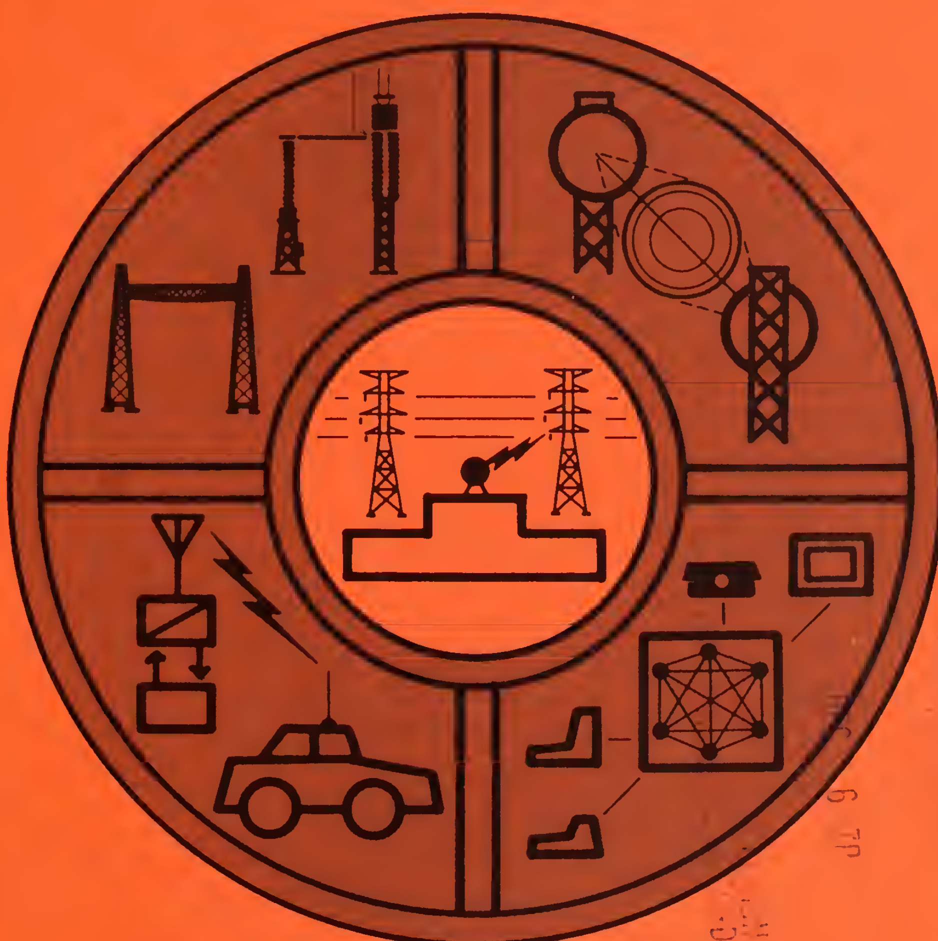
POWER SYSTEM COMMUNICATIONS:

PLANNING AND SELECTION GUIDE



REA BULLETIN 66-4

RURAL ELECTRIFICATION ADMINISTRATION • U.S. DEPARTMENT OF AGRICULTURE
OCTOBER 1978

FOREWORD

REA Bulletin 66-4, "Power System Communications: Planning and Selection Guide," is one of a series of REA bulletins dedicated to power systems communications. This publication is the first of its kind to specifically deal with rural electric cooperatives' planning and selection criteria and is an excellent reference guide. The subject area covers systems planning, selection, costing and implementation.

The step-by-step presentation of the material in this bulletin should be of great benefit to all cooperative engineers and engineering firms and particularly helpful to relatively inexperienced engineers beginning their careers in power systems communications.

Assistant Administrator - Electric

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Power System Communications: Planning and Selection Guide

REA BULLETIN 66-4

POWER SYSTEM COMMUNICATIONS:

PLANNING AND SELECTION GUIDE

POWER SUPPLY AND ENGINEERING STANDARDS DIVISION

RURAL ELECTRIFICATION ADMINISTRATION

U.S. DEPARTMENT OF AGRICULTURE

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

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I. GENERAL

A. Introduction

REA Bulletin 66-4 is the first in a series of bulletins dedicated to Power Systems Communications. REA Bulletin 66-4 deals with planning, selection and implementation of communications systems.

The borrower's management may be called upon to participate in the overall planning of a communications system. A clear understanding of the objectives, requirements, and costs of the system components will assist management in making both viable and timely judgments and will contribute to the overall system implementation.

B. Purpose and Scope

This bulletin is designed to assist management in the planning, selection and procurement of power system communications facilities. The bulletin is intended for both power and distribution type REA borrowers.

Today's electric systems require reliable communications for power system control, operations and maintenance. The power system manager faces choices of increasing complexity when he is called upon to decide among the many types of applications, and then proceed with procuring the specific equipment best suited to his needs.

Alternatives to be considered in selecting communications media are discussed along with some of the factors to consider in making a selection. The cost data that are given are approximate as of the date of printing. They will vary with manufacturer, quantity and other factors, but are offered as a "rule-of thumb" guide for initial planning.

Details concerning particular types of systems such as power line carrier, microwave line-of-sight and mobile radio are given in other REA bulletins /1.

/1 REA Bulletin 66-5: Power Line Carrier and Insulated Static Wire Communications Systems;
REA Bulletin 66-6: Microwave Line of Sight (LOS) Communications Systems;
REA Bulletin 66-7: Plant Communications
REA Bulletin 66-8: Mobile Radio Communications Systems

II. POWER SYSTEM COMMUNICATIONS

A. General

Efficient and reliable communications are vital to every electric utility system. Communications are required between and among points of generation, transmission, distribution, and for maintenance and system operations. This entails protective relaying, telemetering and control, data acquisition and voice communications.

Many rural electric systems are interconnected with neighboring systems to form large inter-connected power systems and communication networks. In order to ensure satisfactory operation, an integrated power system requires close coordination and cooperation among the component systems for accurate control of frequency, sharing of load regulating responsibilities, economic dispatch, system stability, security and protection.

As a result of major power system failures, the importance of improved operator and power dispatcher displays, and the interrelation between automatic generation control (AGC), supervisory control and data acquisition (SCADA) systems, the need for reliable power system communications has become paramount to the electric utility industry.

B. Communications Applications

Most electric cooperative G&T systems are organized according to a hierarchy of control centers. The overall responsibility for the bulk generation and transmission rests with the dispatching center. The dispatch center directs the control of generation to maintain tie-line schedules and frequency, and is responsible for minimizing the cost of generation within the constraints imposed by security. As a result, the dispatch center requires access to the telemetry values of all major tie-line power flows, the power output of all large units or plants, and the system frequency.

Substations within the power system may be manned or unmanned. Unmanned substations are monitored and controlled at a generation, transmission, or distribution dispatch center, depending upon how the electric system is structured. Manned substations may or may not have telemetry equipment installed to enable remote automatic monitoring.

Generating plants, with the exception of some remote hydro or combustion-turbine installations, are staffed with operators and maintenance personnel. The operation of large thermal and hydro plants which is becoming increasingly more complex

and important to electrical systems, involves local control of many plant variables and a high degree of automation in order to achieve reliability and economy.

Figure II-1 is a synopsis of some of the functional communications requirements for the efficient management and operation of a power system.

Conventional Supervisory Control and Data Acquisition (SCADA) systems operate between a master station and a remote terminal unit with the information flow back and forth between these two units. The master station transmits a command to a remote station and accepts data in return from that remote station. Supervisory Control is applied to circuit breakers, transformer tap changers, capacitor banks, DC station service, oil and winding temperatures in transformers, AC station service, transformer high-side overcurrent lockout relays, supply lines, status for transformer switches, voltage and current information, load shedding relays, etc.

Alarm Systems are monitored for status (circuit breaker open or closed) and security against false operations. Status indication and alarms may be typically used for: automatic tap changers, bus voltage, circuit breakers, gas turbine unit alarms, line synchronization, temperature indicators, and others.

Automatic Generation Control (AGC) involves the unit commitment and energy management of the generation system. AGC determines the appropriate generation control action to satisfy power system requirements and monitors the performance of this control. Within the control function; the power required from each generator is calculated and control pulses are sent in response to these requirements, possible system errors such as inadvertent interchange, time deviation, and frequency are monitored and corrected, and programs which calculate generation requirements to satisfy estimated future system loads are constantly updated and verified.

The power system relies on several different types of information signals to provide information indicating breaker or line status, generator status, frequency, MW flows and voltage at selected buses, and MVAR flows required from tie-lines interconnecting individual utilities and power pools. All of this information is critical in maintaining the security of the power system. Telemetry and control functions call for extensive use of communications.

Line protective relaying schemes in many applications employ a communication channel in conjunction with protective relays

Power System Communications Provide for Transmission of:

0 Supervisory Control and Data Acquisition (SCADA) Functions of Substations and Switching Stations

0 Remote Alarm Systems

0 Automatic Generation Control (AGC)

0 Telemetry

0 Pilot Relaying

0 Data

0 Protective Relaying

0 Remote Control of Power Plants

0 Economic Load Dispatch

0 Facsimile

0 Television for Surveillance and Security

0 Voice

Figure II-1 - Power Systems Communications

in order to ascertain, in the minimum time possible, whether a fault is within the protected zone or external to it. High speed determination of the fault location permits simultaneous high speed tripping of all terminals feeding a faulted line. This reduces the damage at the point of fault and usually permits successful automatic reclosing of the tripped circuit breakers to restore the line to service. Equipment protection, such as power transformer banks may also be included as integral parts of a high voltage transmission line. Security and reliability of the communications channel are extremely important for both line and equipment protection.

Economic Load Dispatch communications involve the use of security analysis, resource, load, and support functions data for the proper execution of unit commitment and resources within the power system and between interconnected systems.

Facsimile, television transmission and high speed data are used in the day-to-day operations of power systems.

Voice communications are a valuable tool and indispensable for efficient operation of a power system. Telephony and radio is used for operations, maintenance, and the day-to-day business activities of the utility.

Figure II-2 is a listing of the primary communications media used by power systems.

Power Line Carrier is used where the number of communications channels required is small - typically 1 to 4 channels over a transmission line segment. It has the advantage of using the transmission resources inherent in the power system - the phase conductors.

Mobile radio is used almost exclusively for maintenance and operations. The number of channels that a power system may use is limited by FCC regulations.

Microwave Line-of-Sight (LOS) is by far the most versatile communications media available to power system users. Systems range from as little as 4 voice channels for light density routes to as many as 2700 voice channels. Power system users have rarely exceeded 420 voice channels for specific power system needs.

Wire and cable media properly belong in the lease facilities category. Where economics dictate, they have been placed into service on a purchased basis.

Electric systems may make use of several -- or all of these

POWER SYSTEM COMMUNICATIONS AVAILABLE

- O Power Line Carrier
- O Mobile Radio
- O Microwave - Line of Sight (LOS)
- O Wire and Cable

Figure II-2 - Power Systems Communications Media

media depending upon how extensive are the requirements for communications.

Figure II-3 is a radio frequency allocation chart based upon international agreements reached by various countries. Such frequency allocations and the administrative services pertaining to the use of these bands is governed by mutual consent by the CCIR in Geneva, Switzerland. Power Line Carrier, while not a radiating medium, does fall into the LF band in the United States. Mobile radio uses the VHF and UHF bands, while microwave LOS uses the bands from UHF to EHF inclusively.

C. Characteristics of Communications Systems

The selection of any specific type of communications is predicated upon many factors, several of which have already been discussed, and some which will only surface after the detailed requirements have been set forth. Further, circumstances may be such as to require the use of several types of communications systems within a given power system to satisfy area coverage, channel density, reliability, or such other considerations which may mitigate in favor of a multiplicity of communications media. The five specific communications media we shall discuss herein are:

- Power Line Carrier
- Insulated Static Wire
- Microwave Line-of Sight (LOS)
- Land Lines and Leased Circuits
- Mobile Radio

1. Power Line Carrier

Power line carrier has been one of the most successful power system communications media since its inception over fifty years ago. It has proved to be a highly reliable and relatively low cost means of providing point-to-point communications over distances ranging from a few miles up to several hundred miles. Its principal advantage lies in its utilization of the power transmission conductors as they are usually routed directly to and terminate at the points where communications terminals are needed.

Power line carrier is used for voice communications, telemetering, load control, supervisory control, alarms and protective relaying channels. Carrier frequencies used range from about 30 to 400 kilohertz (kHz).

The principal elements of a power line carrier terminal are: a radio-like transmitter-receiver unit, a carrier-

BAND NUMBER	FREQUENCY RANGE (LOWER LIMIT EXCLUSIVE, UPPER LIMIT INCLUSIVE)	CORRESPONDING METRIC SUBDIVISION	ADJECTIVAL BAND DESIGNATIONS
4	3 to 30 kHz	Myriametric Waves	VLF
5	30 to 300 kHz	Kilometric Waves	LF
6	300 to 3000 kHz	Hectometric Waves	MF
7	3 to 30 MHz	Decametric Waves	HF
8	30 to 300 MHz	Metric Waves	VHF
9	300 to 3000 MHz	Decimetric Waves	UHF
10	3 to 30 GHz	Centimetric Waves	SHF
11	30 to 300 GHz	Millimetric Waves	EHF
12	300 to 3000 GHz or 3 THz	Decimillimetric Waves	

Figure II - 3 - Frequency Allocations According to CCIR Radio Regulations

current coupling capacitor for coupling the carrier-current signals directly into the power line, an impedance matching line tuning unit interposed between the transmitter-receiver unit and the coupling capacitor, and a line trap for confining the carrier-current energy to the desired portion of the power line. These principal elements are shown in Figure II-4.

Where several functions are to be handled by power line carrier, (for example: continuous telemetering, supervisory control and protective relaying), the general practice has been to use separate transmitter-receiver units for each function. However, one set of coupling capacitors and line traps can generally serve several transmitter-receiver units at a given location.

Where several power line carrier channels are carried on the same power line, many systems follow the practice of assigning the lower carrier frequency channels to voice communications, telemetering and supervisory control. The upper frequencies are assigned to protective relaying. Although the upper frequencies exhibit higher attenuation, the distances between protective relay terminals are relatively short. On the other hand, voice, telemetering and supervisory control channels may extend through several substations over relatively greater distances.

Communications may be unattainable under some fault conditions on the line. This characteristic must be taken into consideration in applications where information must be transmitted during a fault.

Consideration must also be given to the ice or frost forming on conductors which causes severe attenuation of the carrier signals. Attenuation due to icing or frost is more severe at the higher frequencies. Many systems avoid using frequencies above 100 kHz on long carrier circuits in climates where severe icing is likely to occur. Ice or frost on conductors also causes a large increase in noise in the received carrier signal, further deteriorating the signal-to-noise ratio. Generally, a frequency-shift narrow-band type of carrier appears to operate during frost or icing conditions much more reliably than FM or AM types carrying voice or tone intelligence.

Power line carrier equipment may operate from the 60 Hz AC electric lines, or it may be battery powered. Battery power is preferable whenever a station battery can be obtainable by station facilities. Separate batteries are sometimes recommended when solid-state carrier equipment is used.

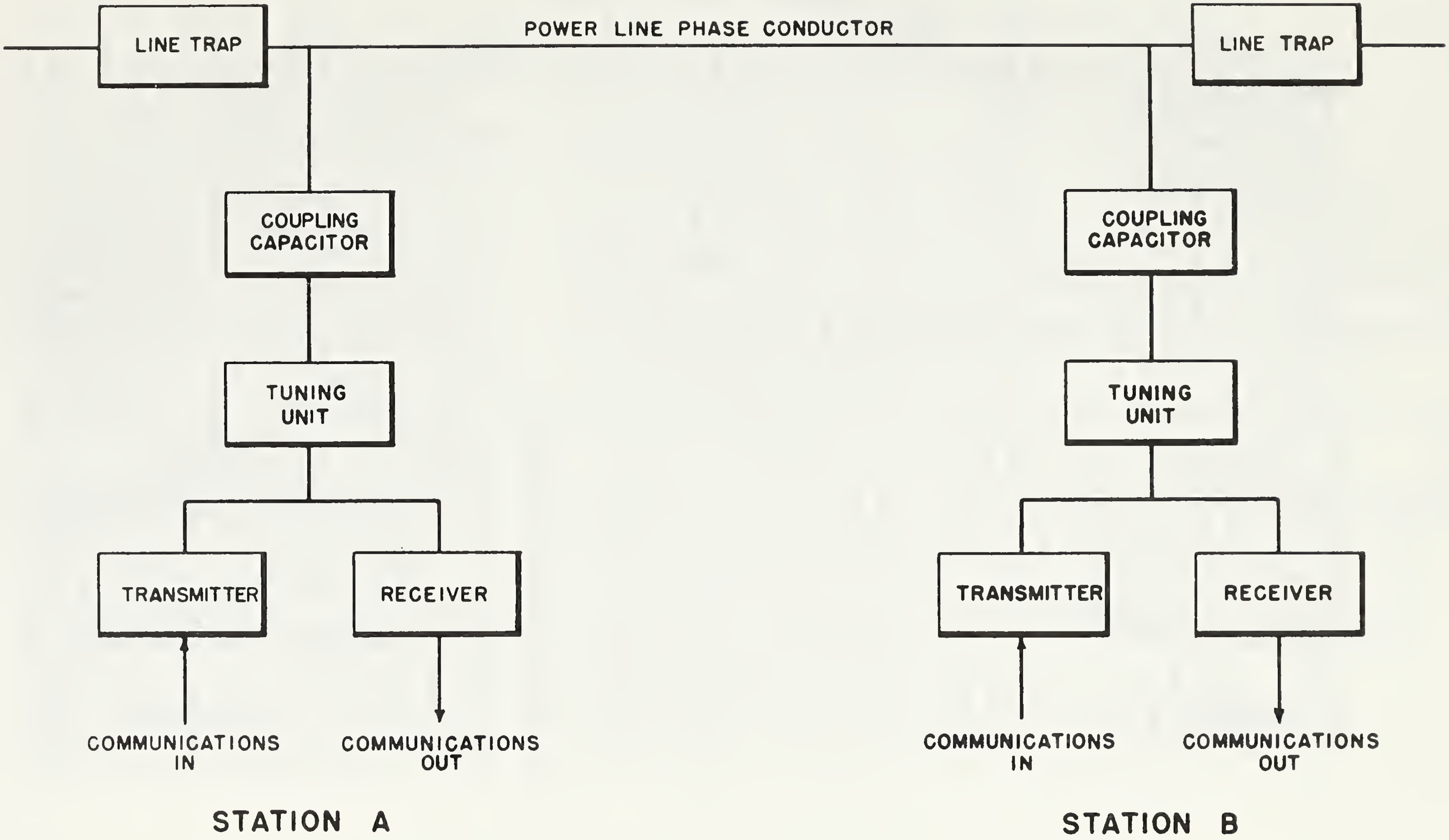

Figure II-4 Principal Elements of a Power Line Carrier System

Recent developments have made power line carrier more attractive than before. Telephone-type multiplexed carrier equipment has been adapted for use on power lines. The development of wide-band coupling and trapping techniques has made this application practical. Up to sixteen voice channels may be utilized, with carrier equipment available in four-voice-channel increments. Each of these voice channels may be sub-multiplexed for tones or digital pulses for use with telemetering or supervisory control equipment.

Each user of power line carrier frequencies is not automatically guaranteed the use of the full carrier spectrum. Operators of neighboring power lines and interconnected systems must coordinate their channel assignments and share the spectrum to prevent interference. Several high-power naval radio stations and some other types of military communications systems, or stations utilizing the power line carrier spectrum, if such a station is located nearby, will certainly interfere with power line carrier operations. Certain types of air navigation equipment also utilize portions of the power line carrier spectrum and if interference were to occur with these services, the power line carrier user would be forced by Federal Communications Commission regulations to vacate the interfering channels. On many of the larger utility systems, the power line carrier spectrum has become fully occupied, and the only satisfactory alternate means for additional communications circuits are telephone leased lines and microwave radio.

2. Insulated Static Wire Carrier

This relatively new means of communication offers a cost advantage as well as several technical advantages. Two overhead static wires, such as are used on H-frame high voltage transmission structures and steel towers, are utilized to convey the carrier current instead of the power conductors. With this method, it is necessary to insulate the static wires at each supporting point rather than ground them. Another departure from the conventional is that the static wires are transposed at intervals to minimize the effects of electromagnetic induction. Figure II-5 illustrates the elements of an insulated static wire carrier system. Insulating the static wires is a radical departure from the earlier philosophy that static wires should be solidly grounded at each structure. However, by using relatively small, gapped-to-ground insulators whose size is governed solely by the mechanical strength requirements, the static wires are effectively insulated for carrier communications purposes, but still perform their

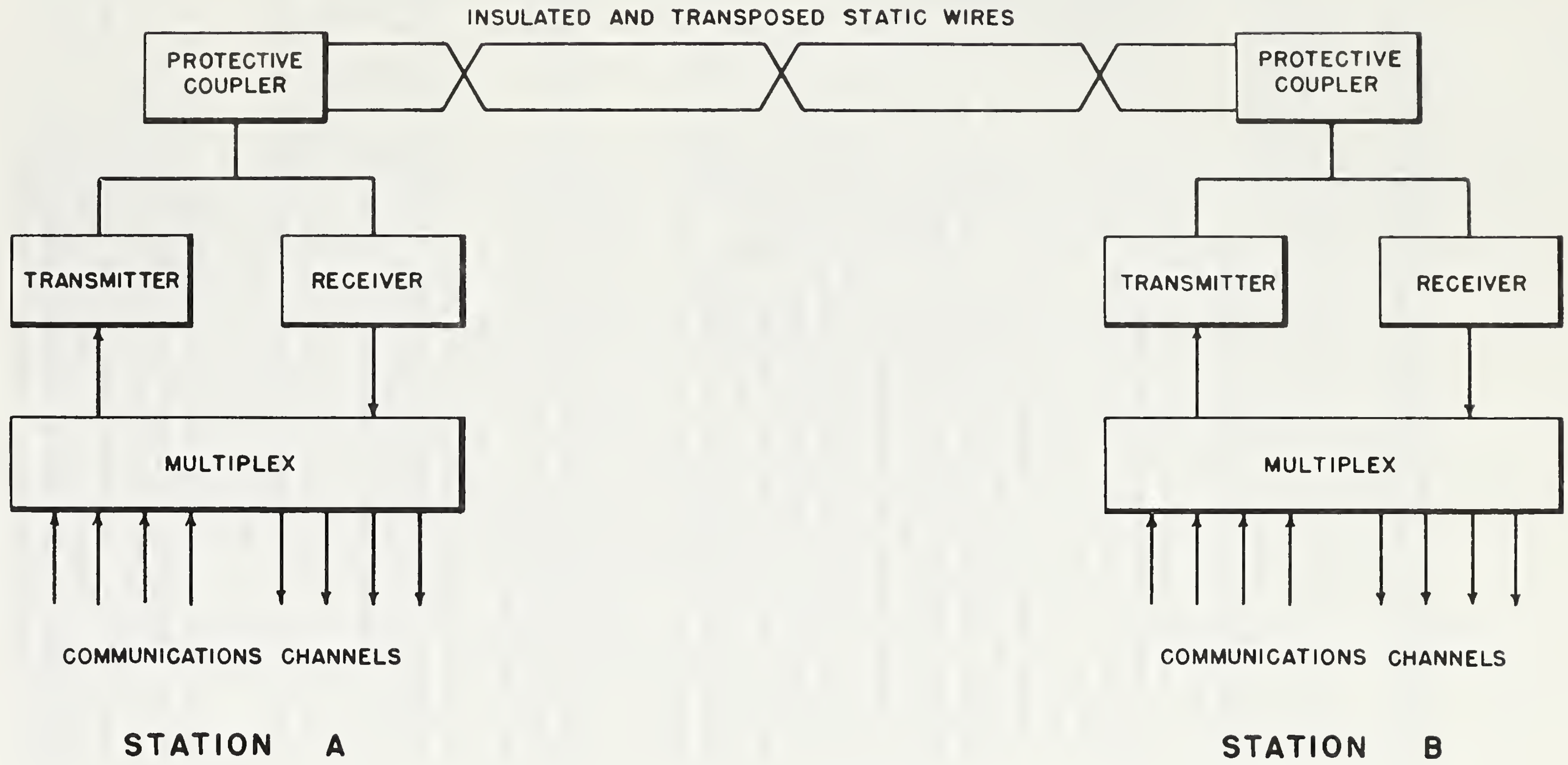

Figure II-5 Principal Elements of an Insulated Static Wire Carrier System (Multiplexed).

prime function of shielding the line from lightning. The need for good grounds at each structure still exists.

Improved carrier transmission characteristics may be obtained by utilizing static wires of copper or aluminum covered steel wires. Higher conductivity permits the use of longer circuits and provides improved signal-to-noise ratios without the need for repeaters.

The use of insulated static wire carrier offers several additional advantages. The need for carrier by-pass devices at substations and switching stations is eliminated because the insulated static wire can be carried straight through without interruption. This can account for considerable savings, especially when a carrier circuit is routed through several substations or switching stations. Another advantage is that the full carrier spectrum may be more easily utilized. This permits multiplexing the carrier to derive up to 16 voice channels. Expensive broadband traps and broadband power line coupling devices are not required. Herein lies a major advantage of insulated static wire carrier. However, a full carrier spectrum may not be available on static wire lines where carrier current from neighboring interconnections may be present on phase wires. These signals have a tendency to couple into the static wire circuits. Coordination between phase wire carrier and static wire carrier will be necessary in most cases.

Attenuation from frost or ice may also be a problem on static wire carrier and may tend to continue longer than ice on phase wires due to the slight heating in current carrying conductors.

On new transmission line construction, consideration should be given to insulating and transposing the static wires where carrier communication is contemplated. Many electric utilities are following this trend. The cost of insulating the static wires may possibly be regained during the life of the line from line loss savings, and the future use of the static wires for communications purposes will result in minimum future cost.

Protective relay engineers have expressed doubts as to the use of static wire carrier for protective relaying channels. This has prompted recent field tests to ascertain the reliability of static wire carrier for protective relaying purposes. These tests, though not conclusive, indicate that static wire carrier relaying channels may be equally as reliable as power line carrier relaying channels.

Observations covering years of operating experience also indicate that lightning protection of the line is not degraded by insulating the static wires.

3. Microwave Radio

Microwave radio, commercially introduced more than three decades ago, has proved to be a highly satisfactory communications medium for electric power systems. Its principal advantages are high reliability and low cost on a channel-mile basis when many channels are required. Figure II-6 illustrates the principal elements of a microwave communications system.

Microwave radio channels will handle any type of intelligence that can be handled over wire lines or power line carrier. Additionally, microwave will handle wide-band requirements that ordinary wire lines and power line carrier are not capable of handling. Industrial television is an example. The wide-band capabilities of microwave radio permit multiplexing to provide up to 2700 high grade voice channels, or equivalent. This, of course, is far more channels than would normally be used by most electric utility systems. However, the use of 25 to 300 channels is quite common for large utilities. The need for less than ten voice channels, or equivalent, makes it difficult to justify the use of microwave, if cost is the primary consideration.

Microwave radio energy is propagated from station to station in a narrow beam, much like a searchlight beam. It is capable of reflection and refraction. The microwave beam path approximates a straight line and is sometimes referred to as a line-of-sight path. This is a rough approximation and great care and engineering skill must be applied in determining the exact path or paths if reliable service is to be obtained. Such an engineering study is known as a microwave path survey. These studies are generally made by engineering firms that specialize in microwave radio communications.

A microwave beam will normally refract or bend slightly in the same direction as the curvature of the earth. The curvature of the beam will vary from time to time. Sometimes the beam will actually follow a straight line. For relatively short periods the beam will curve in the opposite direction of the earth's curvature. The amount and frequency of this beam bending is statistically predictable and is taken into account when a path survey is made. The curvature of the earth itself tends to block the beam and thus becomes a prime factor in determining the height and spacing of antenna towers. If natural or man-made objects are interposed in

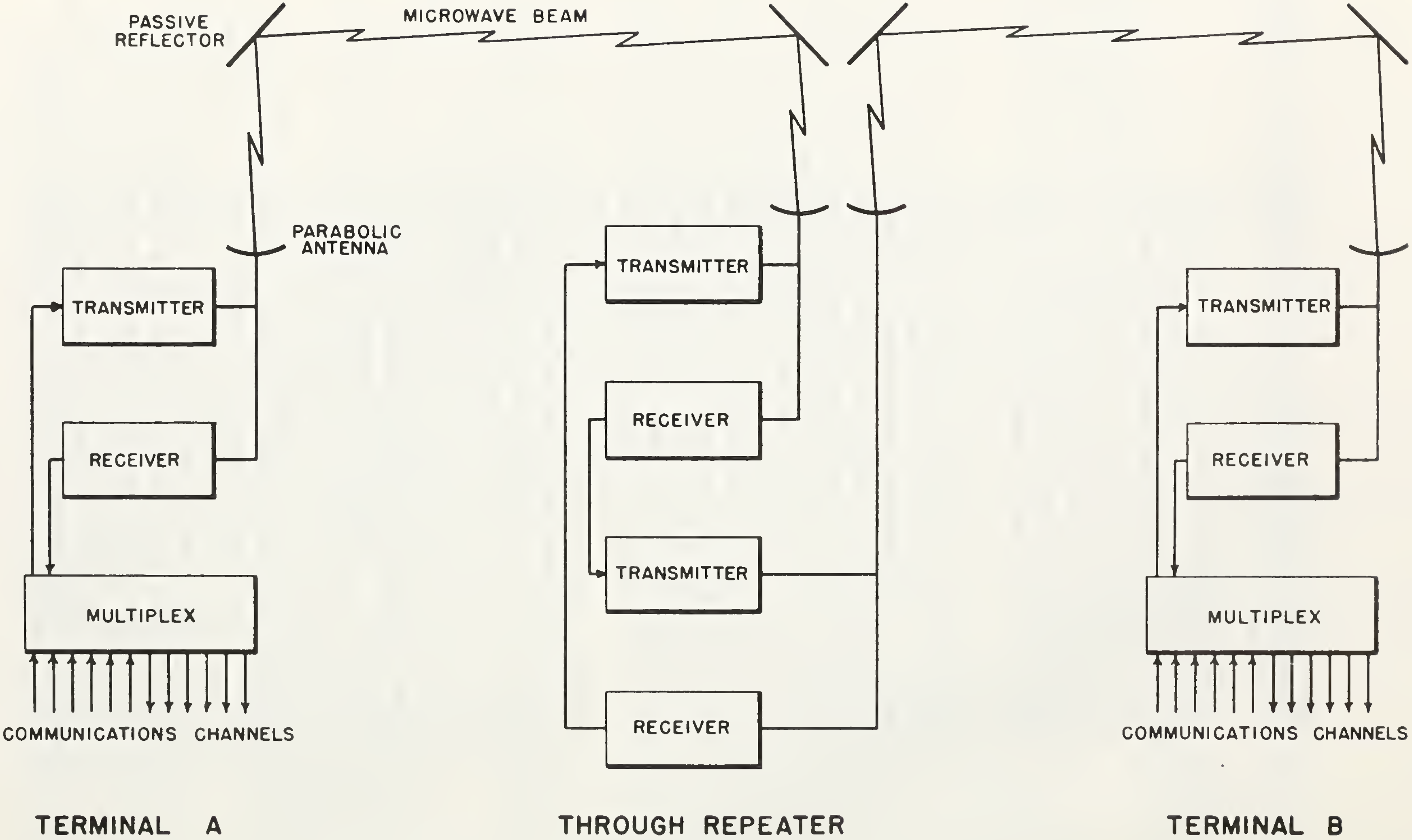

Figure II-6 Principal Elements of a Microwave Communications System

the path, the beam will also be blocked and the signals will not get through. This same blocking effect will happen if the beam "sags" into the earth. Stated another way, the beam will be blocked if the earth "bulges" into the beam path. This reverse beam bending phenomenon is sometimes called "earth bulging."

Path characteristics vary in different parts of the country. Geographical locations and climatic conditions must be taken into account in addition to topographical considerations. For example, in coastal areas and over coastal waters where fog is present, propagation conditions are most difficult. The Great Plains region and the East, in general, offer average propagation conditions. The Rocky Mountain region offers the best propagation conditions.

Since propagation conditions can be expected to vary from time to time, it is good practice to provide a received signal level that is much higher than is actually needed most of the time. The excess signal level is available to allow for and to compensate for deep fades. This provides a safety margin to insure good propagation reliability. It also provides for deterioration in transmitter output and in receiver sensitivity. Modern practice requires fade margins of 35 to 40 decibels.

All of the above factors are taken into account when the path survey is made. A path survey is necessary before accurate cost estimates of the microwave system can be determined. An equipment supplier cannot make an accurate estimate or bid to furnish and install a microwave system unless path survey information is available to him. He can guarantee the performance of the installed system but his guarantee will necessarily be based on the accuracy of the path survey. Errors in the path survey may prove costly to all concerned. The organization performing the survey should guarantee in writing the accuracy of its path survey. Some users further require the equipment supplier to be responsible for the accuracy of the path survey and to guarantee the system performance accordingly.

The older microwave systems used by electric utilities operate in the 960 megacycle band. These systems are generally used for low channel density. Next came the 2,000 megacycle systems capable of handling more channels and adapted for longer hauls. Currently, the 6,000 megacycle systems are most popular among the electric utilities. These are the systems that are capable of handling 420 voice channels. An advantage of these 6,000 megacycle systems is that narrow beams can be obtained with relatively small parabolic antennas. Narrow

beams mean high gain at both sending and receiving ends. High gain means that higher fade margins are attainable and also that less RF power is required. Another advantage is that narrow beams permit the use of relatively small passive reflectors at the top of the antenna towers thus making it possible to keep the parabolic antennas at ground level near the transmitter-receiver units. This means short antenna feed lines with low losses. It also makes the parabolic antennas readily accessible for inspection and maintenance. On the other hand, narrow beams mean that sturdier, more expensive towers are required to keep the beam on target.

The maximum distance between two microwave stations depends upon a number of factors including antenna height, intervening topographical obstacles, geographic area, climate conditions, permissible fade margin and degree of reliability required. A conservative figure for estimating purposes is 40 kilometers (km). Thus, to span an 80-kilometer distance, two end terminals and an interposed repeater are required. An end terminal, for duplex operation, requires a minimum of one transmitter and one receiver with multiplexing equipment, while an active repeater station requires two transmitters and two receivers but no multiplexing equipment.

Due consideration must be given to proper housing conditions for electronic equipment, particularly where long life and high reliability are required and where equipment must be maintained for years on as nearly a continuous basis as possible.

The basic requirements for a building housing electronic equipment include the following considerations: Power must be continuous and well-regulated. The housing of standby engine-generator or fuel or corrosive-gassing type batteries in the same room with electronic equipment has been found to be poor practice because of heat and fire hazards and corrosion damage to equipment. Vibration and noise must be kept to a minimum in order to reduce outages created by component shorts and open circuits. Moisture and humidity must be held to a minimum and relatively constant, otherwise corrosion, rust and resistance changes are accelerated. Dirt and dust have an electrostatic affinity to electronic equipment and must be kept to a minimum, particularly electrically conductive types. Temperature must be held reasonably low and constant. A room temperature between 16° and 32° C is recommended. Critical operating conditions will result where temperatures exceed 38° C and where temperatures fluctuate frequently over a range of 10°C.

Refrigerated air conditioning is recommended for installations

where considerable thermal radiation is present and must be dissipated. In addition to controlling temperatures to a practical range, the air conditioner will minimize the influx of dirt into the building and will effect a reduction in air moisture. Air conditioning is seldom needed where high ambient temperatures do not occur. In any situation, however, all ventilation openings should be equipped with dust filters, and doors and other openings should be weather-stripped to prevent dust from entering.

A separate room is recommended for housing the emergency power source. Fuel must be safely stored. Adequate forced air ventilation and circulation between inside and outside of building is necessary for engines. Where snow can be deep, vents above snow levels must be provided for engine exhaust, fuel tank and air circulation. Also, roof-top entrance trap doors are sometimes necessary in heavy snow areas.

Housing and tower construction on any site should be sturdy and in keeping with site requirements. Towers should meet Electronic Industries Association (E.I.A.) standards. Foundations should be of liberal design, appropriate to local soil, terrain, weather, winds and earthquakes. Concrete housing designs, either poured, block or tilt-up are popular. Fiberglass buildings are gaining wide acceptance for use on microwave systems. Prefabricated buildings, insulated and made dust tight and designed especially for microwave installations are low in cost and are also popular. The concrete types do have an advantage in that they afford better protection from damage to equipment by vandal gun fire. Several instances of this type of damage have been reported.

Tower location, lighting and painting must be in accordance with Federal Aviation Agency and Federal Communications Commission regulations. REA Bulletin 40-3, "Structures That May Affect the Use of Navigable Airspace," outlines FAA requirements. Since towers are often located near substations or power plants, careful overall planning must be done to prevent guy wires from interfering with line rights-of-way and plant expansion. Guy wires must also be protected from possible contact or damage by vehicles.

Securing reliable power is the most important single operating phase of a microwave installation. First of all, the use to which the communication service is put must be considered and whether it may be interrupted at all, and if so, for how long. Should 100 percent service be the requirement, then the solution may be intricate and expensive. In situations where momentary interruptions cannot be tolerated, the use of batteries with rectifier chargers is the simplest

solution if DC powered solid-state type microwave equipment is used. Momentary interruptions due to power failure cannot be tolerated on protective relaying channels. Protective relays must operate at the instant a fault occurs. At that instant the microwave channel may momentarily drop out if its input power is derived from the 60 Hertz system source.

If it is also necessary to maintain continuous communications service during long interruptions of power, then engine-driven battery chargers will also be required to sustain the batteries.

If momentary communications interruptions can be tolerated, but not sustained interruptions, engine-driven 60 Hz generators for emergency standby use are a low cost practical solution for AC operated microwave equipment.

The exposure to lightning of microwave installations is much greater than ordinarily experienced by other types of plant. This is primarily because of the tall antenna towers which are certain to receive many direct and intense lightning strokes. Special provision must be made for safely dissipating these charges into the earth to prevent damage to tower footings, buildings and equipment. Shock hazard to operating personnel, resulting from potential differences between metal objects within the equipment building, must also be reduced to a minimum.

4. Land Lines and Leased Circuits

In many situations where short-haul communications circuits are needed, land lines owned outright by the user or leased from the telephone company may be the most economical solution. Land lines may be open wires on poles, aerial cable, direct buried cable or cable in ducts. (Leased circuits may also contain some microwave links.) Where high reliability is required, stormproofed construction is specified. Alternate routings are often used and spare cables are provided. Land lines, like microwave, may be multiplexed for voice or data channels. Voice-frequency loaded cable, however, cannot be multiplexed for voice channels.

In rural areas, overhead wire lines or buried cable are often placed along the power system rights-of-way. However, construction problems and legal problems become more complex when urban and suburban areas are approached. Costs may soar and get out of hand. Under these latter conditions the best solution may be to lease the required circuits from the local telephone company.

Telephone companies usually can provide any type of communications service at almost any degree of reliability specified. Sometimes high reliability is built into existing plant and the lessee receives high reliability service at no extra charge. On the other hand, if reliability specified by the lessee exceeds that which is available in existing plant, then the lessee will have to pay an additional amount to cover his share of the stormproofed facilities constructed especially for his needs.

Tariffs for existing facilities are nominal and, in general, leased circuits are the least expensive of any communication method for relatively short distances when only a few communications channels are needed.

For longer distances where a larger number of channels are involved, cost factors may favor user-owned facilities.

Other considerations that are often weighed before deciding the question of owning versus leasing communications circuits are:

- Will the route to be provided be reasonably free from potential outages due to vehicular traffic hazards, exposure to high voltage contacts, flood, hail, excessive rainfall, windstorm, sabotage, temperature inversion, interruptions in service caused by errors of maintenance forces in changing wire terminals, and interruptions in service caused by strikes in the contracting service?

- What alternate means of communication are available in the event of failure of the line?

- Does the leased communications route involve more than one telephone company, and how is responsibility divided?

- What additional protective equipment is required on leased facilities?

- Does the telephone company maintenance personnel thoroughly understand circuits used to control protective relays?

- How many hours per day are there qualified personnel on duty to speed up the restoration of interrupted communication facilities?

- How does the flexibility of owned versus leased facilities compare? What is the cost and time involved in adding additional voice channels?

- What percent reliability is required and what will it cost to attain?

- To what degree will the use of leased facilities modify the existing requirements for communications maintenance and supervisory personnel?

- How would costs compare, over at least a ten-year period, giving due consideration to expansion of the system in both number and types of communications circuits?

5. Mobile Radio Communications

Vehicular radio communication is an indispensable tool of any electric power communications system. It is a standard practice to provide maintenance, operations, and supervisory personnel with two-way mobile radio for communication between office and vehicle and from vehicle to vehicle.

Mobile radio systems provide the transmission means for the exchange of information between moving and fixed locations. They connect private or public control centers and telephone networks to radio equipped vehicles or persons providing a communications link when a location is removed from ready telephone access. Often the vehicle or man is in motion, causing constantly changing parameters in the radio transmission path, which is a major concern in the design of mobile radio systems.

Typical vehicular mobile radio systems, whether dispatch or radio-telephone oriented, possess many common requirements. There are the vehicle mounted or hand carried radio and the fixed land or base station radio. The latter generally uses an omni-directional antenna to obtain uniform radio coverage of an area. Often, the radio and antenna system for the base station are located on top of a high building, broadcast or TV radio tower or a hilltop with a commanding view of the service area of the mobile radio system. The high base station antenna location generally has a reciprocal advantage for the mobile equipment since it permits optimal "talk-back" range for a given service area. The ideal radio path between a base station and mobile station is one as free of obstruction as possible. Such a path, when unobstructed, is referred to as being "line-of-sight." High buildings or hills between these stations can cause radio shadows resulting in poor reception.

Common engineering considerations in planning a mobile radio

system include:

- The size of the area and the type of terrain over which communications are required
- The selection of an operational frequency, or frequencies
- The "control" facilities: number and location of control points; use of special signaling arrangements (i.e., single or two-tone pulse tone equipment, digital dialing equipment, etc.)
- Number of radio equipped vehicles and personal portable radio units
- Potential sources of radio channel interference.

Adequate coverage is the prime requirement of a mobile radio system design. The objective is to identify and eliminate dead spots or noisy reception within the desired radio coverage area. The following factors give some insight into what affects mobile radio coverage:

- Base station antenna height above average ground elevation
- Type of terrain -- level, hilly, mountainous, open country or built-up metropolitan areas
- Operating frequency
- Antenna gain (base station and mobile)
- Transmitter power (at base mobile station). The limiting factor is generally mobile transmitter talk-back range. Base station transmitters are generally of higher power than mobile transmitters so that the systems dispatcher is able to reach users in locations where mobile talk-back is difficult. The mobile can move to a more suitable location to talk back when advised of the problem by the dispatcher
- Ambient electrical noise level at the base or mobile station. Note: Electrical noise is primarily from man-made sources such as power transmission lines, power generators, automobile ignition systems and other radio systems. Such interference must be considered in determining coverage reliability.

The FCC is the major regulatory body with which mobile radio system designers can expect to coordinate regarding application

and planning. The major issue which the designer can expect to have to resolve with the FCC is his frequency requirements. The frequencies available to all classes of users, other than Federal Government agencies, are listed in the FCC Rules and Regulations. Volume V includes Part 89 (Public Safety Radio Services), Part 87 (Aviation Services), Part 91 (Industrial Radio Services) and Part 93 (Land Transportation Radio Services). Volume I includes Part 17 covering construction, marking and lighting of antenna structures, and Volume II includes Part 2, which pertains to general rules and regulations governing all of the non-government services. Federal Government users such as the Air Force, the FBI, U.S. Forest Service, etc., are allocated frequencies by the Inter-Departmental Radio Advisory Committee (IRAC).

With some exceptions, most classes of users have blocks of frequencies in each of the three land mobile bands. With the advent of the FCC Chicago Frequency Management Center, the blocks system is being supplanted in some degree by the pooled concept in which frequencies are shared across many classes of users. An important part of the application engineering is to choose a frequency band or frequencies which are best suited for a particular system.

Most user groups are assisting the FCC in the orderly management of frequencies by appointment of frequency coordinators strategically located throughout the country who act in an advisory capacity. Where such coordination has been set up, each application to the FCC for a new or modified license in that particular service must be accompanied by a letter from a recognized coordinator recommending or endorsing the use of a certain frequency or frequencies. Alternatively, a user may conduct an independent engineering study for submission to the FCC with his license application.

Frequency coordination is carried out in most of the Public Safety Services by the locally appointed government frequency coordinator. The private industries also practice frequency coordination, including the Special Industrial Service, the National Association of Manufacturers, the Utilities Telecommunications Council (UTC), the American Association of Railroads, the Motor Carrier Service, the Taxi Cab Radio Service, the Petroleum Radio Service, and the Business Radio Service (NABER).

The trend in modern mobile radio equipment design is towards improved reliability, better operating characteristics and reduced packaging size. The average 100 watt solid-state VHF-FM mobile transceiver today occupies less than one cubic foot of volume, requires no special power supply as it runs directly off a 12-volt dc source such as an automobile storage battery,

and requires maintenance at greater than yearly intervals. Mobile equipment as well as its base station counterpart are fully solid-state up to the 100 watt power level. Higher power levels are generally not required but can be achieved by adding on a high efficiency forced air or conduction cooled ceramic tetrode amplifier. Where the FCC station license permits, power levels up to 1,000 watts at VHF and UHF frequencies may be used. Power levels are strictly controlled by FCC regulation in accordance with the class of user license and required coverage area.

Today's equipment is almost entirely modular in construction. It is common industry practice now to design an entire receiver onto a single printed circuit board or group of smaller plug-in printed circuit modules -- a technique "borrowed" from the computer industry. Modular construction greatly increases equipment reliability and therefore reduces costly maintenance time.

One-way (simplex) "push-to-talk" operation is the usual method of operation, as it requires only one channel. With this method, all transmitters and receivers in the system are tuned to the same channel.

Duplex operation is sometimes employed on large, high density systems. Here all base station transmitters and all mobile station receivers are tuned to one channel, and all mobile station transmitters and all base station receivers are tuned to a second channel.

Radio relay links using VHF and UHF channels and microwave channels are often employed to link a remotely located base station with the radio dispatcher's location.

A mobile relay station is a special type of relay that is used extensively by electric utilities. The mobile relay station is installed at a suitable fixed location, and its primary function is to automatically relay messages from one mobile station to another mobile station. The mobile relay makes it possible to greatly extend the mobile-to-mobile range in a VHF radio system. It will also extend the range of operation between a base station and mobile stations.

The simplest type of mobile radio system is illustrated in Figure II-7. It consists of a locally controlled base station and a number of mobile radios. Local control means that the squelch and volume controls, power on/off switch, microphone jack and loudspeaker are built into the base station cabinet, and are immediately accessible by the operator, or that such controls, etc., are mounted in a small operator's control panel or box

which is wired directly to a base station located near the operator; i.e., same building or property. (Local control is further defined by FCC Rules and Regulations, Volume V, Part 91, Section 91.107.) A single frequency is employed and consequently conversations are a "party-line" affair, as any radio can hear and talk to any other radio within range; i.e., base to mobile, mobile to base, or mobile to mobile. This simple system is quite common in low-band (30-50 mHz) and high-band (150-170 mHz) services. The base station installation includes its antenna and transmission line. At mobile radio frequencies, the higher the antenna with respect to the surrounding area, the better the coverage obtained.

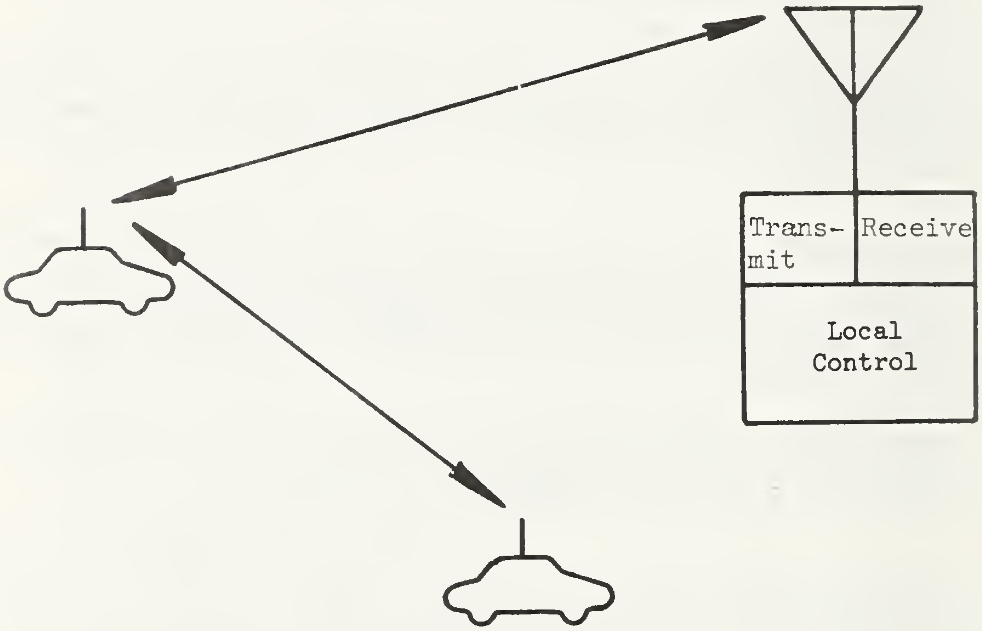

Figure II-7 - Basic Two-Way Mobile Radio System

D. Capabilities and Comparison of Communications Media

Tables II-1 through II-4 provide a comparison of the capabilities of different communications media in terms of their advantages and disadvantages.

Table II-1

Power Line Carrier

Summary and Comparison

Advantages	Disadvantages
1. Economical for small number of channels over long distances.	1. Susceptible to power line noise.
2. Extremely reliable.	2. Limited frequency spectrum.
3. Repeaters unnecessary for transmission over long distances.	3. Potentially hazardous to maintenance personnel.
4. Uses power system facilities.	4. Costly to expand
5. Most economically serves remote substations.	5. Limited data transmission speed.
6. Adaptable to complete telephone service.	6. Costly to provide redundant (diversity) communications.
7. Proximity to control and data acquisition information.	7. Requires ancillary devices to attain high voice channel signal-to-noise performance.
8. Provides highest system reliability over closed loop power system at least cost.	8. Loss of service of transmission line could result in loss of communications.
9. Interface equipment minimal	
10. Does not presently require FCC License.	
11. Not subject to environmental impact criteria or constraints.	

Table II-2
Microwave Line-of-Sight
Summary and Comparison

Advantages	Disadvantages
1. Capable of transmitting a large number of channels.	1. Requires licensing by FCC.
2. Propagation through free space. Not affected by power line faults or changes.	2. Must meet environmental impact criteria for towers 300 feet and higher.
3. Not affected by power line noise.	3. Subject to interference from other LOS systems.
4. Large frequency spectrum available.	4. Requires relatively large capital investment.
5. Lowest cost per channel to augment.	5. Requires highly skilled personnel to maintain and operate.
6. Inexpensive to ensure propagation reliability.	6. Very expensive for low density (few channels) systems.
7. Excellent system performance available.	7. Often requires purchase of additional land for site locations.
8. Provides superior high speed data service.	8. Subject to propagation signal fluctuations.
9. Inexpensive to add additional RF links to existing system.	9. Requires capital investment in test equipment.
10. Maximum versatility for expansion.	10. Generally requires specialized consulting engineers to prepare plans and specifications.
11. Able to handle any signal format needed for power system communications.	

Table II-3
Land Lines - Leased Facilities
Summary and Comparison

Advantages	Disadvantages
1. Most economical for transmission over short distances.	1. Overhead lines susceptible to most hazards of nature.
2. Operations and maintenance personnel not required.	2. Performance not under user control.
3. No capital investment required	3. Difficult to obtain dedicated channels.
4. Excellent performance available.	4. System security difficult to obtain.
5. Service may be acquired as needed.	5. Difficult to obtain economical service to remote facilities.
6. High-speed data capability.	6. Service is costly.
7. Provides virtually any communications service needed.	7. Requires extensive coordination to obtain service over large areas when specialized channels are required (i.e., for protective relaying and SCADA signals).
8. No spare parts inventory or test equipment need be maintained.	8. Maintenance service on a first come - first served basis.
9. Specialized channel conditioning readily available.	
10. Interconnect responsibility left to others.	
11. No additional facilities required.	
12. Adaptable to system changes.	

Table II-4
Mobile Radio
Summary and Comparison

Advantages	Disadvantages
1. Compact and lightweight.	1. Requires FCC licensing.
2. Modest capital outlay.	2. Subject to large signal fluctuations.
3. Highly mobile - may be placed where needed.	3. Limited channel capacity.
4. Signaling schemes allow maximum use of a single RF channel.	4. Lowest data transmission capability.
5. May be conveniently remoted to other facilities for round-the-clock use.	5. High cost per channel.
6. Range may be extended via microwave interconnect.	6. Performance criteria difficult to specify and ascertain.
7. Highly flexible - may be configured as needs dictate.	7. Requires additional interface equipment to place on microwave system.
8. Requires minimal operator skills.	8. Subject to environmental impact criteria on structures 300 feet or higher.
	9. Subject to interference from other systems.

III. DEVELOPMENT, PLANNING, AND DESIGN OF CRITERIA

A. General

It is important at the inception of a project that the borrower coordinate communications plans and requirements with REA. The initial contact allows both REA and the borrower to review the needs, goals, and intended use of the proposed communications system. It also provides REA with an overview of the ongoing efforts of cooperatives in a given area. This is important because many borrowers are planning and/or building systems in close proximity to one another. These efforts may require close coordination to avoid duplication of facilities and, in fact, may result in a sharing of facilities with the attendant benefit of a reduction in overall costs. This, of course, will depend upon the specific uses of the system being contemplated and its need for security.

B. Communications Planning

Communications planning involves a variety of tasks and is a continuous effort. It is an iteration of three fundamental steps:

- Determining the requirements
- Formulating a basic system concept
- Developing a communications plan

From the moment of inception until the final plan is achieved, each of the above steps interacts with the other to produce a new plan. This is termed the planning phase. Without this phase, the activities of the communications staff are merely reactions to a set of ever-changing requirements and attendant problems. Using a systems approach to a design problem differs from trial and error methods. Within the framework of the systems approach we attempt to identify the influences and constraints on the set of requirements. These factors cause a preliminary design to manifest itself in terms of a desired result. This result is translated into a functional system against which a procurement specification is prepared.

The implementation of the systems approach involves a planning sequence. The following steps are illustrative of one such methodology used to accomplish the overall planning effort:

- Define the problem. In defining the problem, the objectives to be achieved by the proposed system should be adequately delineated. Clearly define and analyze: the ramifications

of the problem, the interrelationships between the problem at hand and other problems and situations uncovered while identifying the problem. State the objectives to be met as well as the scope of the project.

The results of this step should be documented along with the logic used to arrive at the problem definition and analyses.

- Prepare an outline of the approach and methodology to be used in studying and designing the proposed system. This outline is to be used in organizing a detailed plan of action. The outline should identify:

    - Sources of information to be used
    - Types of information to be collected
    - Analyses to be performed
    - Schedule of activities
    - Goals to be achieved
    - Schedule of time and costs

- Obtain data and information on the areas that will be affected by the proposed communications system. It is imperative that the responsible person have a basic knowledge of utility systems and operations.

- Analyze the interaction between and among the users that are affected by the proposed communications system. These interactions should be defined and analyzed in terms of inputs and outputs of each organizational unit or user of the intended system.

- Make a thorough study and understand the existing system. It is important to know both the strengths and weaknesses as well as the expansion capabilities and limitations of the current system. The result of this step should be a thorough understanding of the information flow into, out of, and throughout the present system.

- Define the proposed system's requirements. These requirements are to be defined in terms of the framework of the goals and objectives originally set forth.

- Distinguish between requirements and desirable features. Be quantitative, precise, and performance oriented. Further, distinguish between requirements and solutions -- solutions are later.

- Using the requirements defined above, design the proposed system. Time and costs permitting, it is desirable to go through an iterative design process using alternate system designs.

- Develop the cost comparisons for the various alternative designs. Select the system configuration that best meets both the cost and system requirements. This should be the result of an optimization process.

- Submit proposed study and plans to management for approval. Coordination and approval of interfacing power systems should also be obtained. Subsequently submit study/plan to REA for review, coordination, and approval in accordance with REA Bulletin 40-6.

- After REA approval, release the specifications for competitive bidding in accordance with REA Bulletin 40-6.

- Systems implementation. In the implementation process, the management and engineering staffs participate jointly in the procurement, development, installation, testing, and cutover for operation of the system.

C. Development of Design Requirements

The defining of the communciation requirements is the first step in developing the design requirements. It is not possible to write a general equation as a starting point for each particular set of communications needs likely to be encountered. The permutation of ideas, results, and problems would yield an almost unlimited set of terms to be solved.

The basic precept to system design involves investigation of various design factors (to obtain those which are pertinent), their limitations and constraints as they relate to the total design task.

After the requirements have been defined and potential solutions delineated, the task of selecting one of the several

alternative solutions for each design factor is performed. The expected performance for the various segments of the system must be evaluated against the offsetting influences of performance impairments, costs, and availability of technology.

Once the basic system has been defined, consideration must be given to the performance factors which can influence the design -- noise and distortion. A criterion of acceptable quality must be established for each type of information to be transmitted. This criterion takes into account the requirements of the user of the information as well as the information itself. The goal here is to ascertain the minimum amount of information to be transmitted and received to effect a judgment. Human speech has a high order of redundancy and can tolerate substantial impairment before unintelligibility results. On the other hand, certain control and telemetry information is so vital to power system operation that high noise levels or signal distortions will render the message unusable and may cause undesirable effects on the overall power system's operation and performance.

Starting at the top of Figure III-1, the first question posed is "What is required?" This is the requirement definition stage, requiring a clear understanding of the information to be transmitted and what use the user intends to make of the information. When the requirements and objectives have not been clearly defined, the figure shows a return to the beginning stage or a re-evaluation of the requirements. This is done for each objective until it is reasonably certain that the basic criteria are sound and defined as far as possible. If certain factors cannot be further defined, the known requirements can be carried through the evaluation process, thus allowing a wide range of values to be applied to the unknown factors. This will tend to complicate the process somewhat and leads to a qualified solution. However, even a "qualified solution" will assist in defining the overall communication requirement.

The next question asks "How much?" What is the traffic volume? What are the number of channels required? In other words, a quantity problem. The best way to handle this part of the design phase is to start with the known present traffic volume of the existing system and correlate the expected volume growth during the desired period. Depending upon the complexity of the system, the answer to this question may involve a full-scale traffic study.

After the objectives have been defined and the amount of communications determined, the next question will be "What is the quality of service desired?" This involves setting down the original objectives with the known volume requirements and

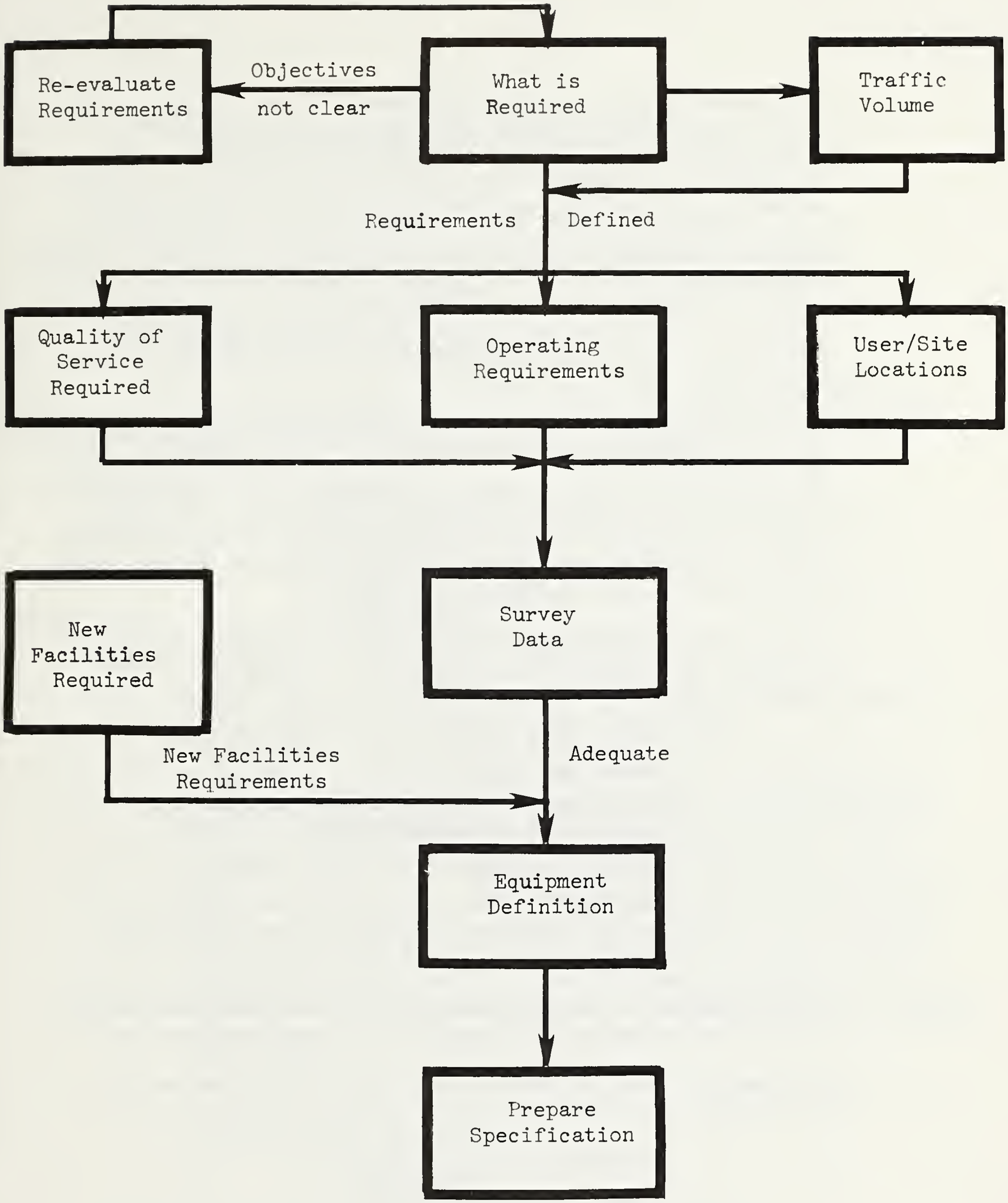

Figure III-1 Flow Chart for Development of Design Requirements

determining the technical performance. At this stage, it is necessary to ascertain the operating requirements for the system and to establish the service schedule as well as where the users are located in the system. Consideration of these parameters will yield desirable objectives and when carried forth with the actual site/facilities survey of available resources, facilities, and transmission media available, a certain basic system definition will arise. It may happen that the survey indicates that the existing facilities are either inadequate or do not exist. Therefore, new facilities are required or the original objectives may be either compromised or sacrificed.

When the question of facilities has been resolved and the design requirements have been translated into design parameters, the selection of equipments corresponding to the most desirable medium for transmission may be carried out. This will involve surveying the present state of the art, visiting vendors to determine techniques of transmission, reception, signal processing, and equipment availability.

At this point the staff should review the proposed communications system and evaluate the design. A comparison of the following should be made:

- Quality and reliability vs. capital and operating costs;
- Serviceability and personnel required vs. capital and operating costs;
- Growth and expandability vs. capital and operating costs;
- Obsolescence vs. capital cost for flexibility and expansion.

If the evaluation is satisfactory, the communications system's specifications should be prepared and the system procured.

To summarize, the following constitute the fundamental system design parameters:

- Information to be transmitted
- Communications objectives
- Traffic volume
- Quality or grade of service
- Operating requirements
- System geography

- Facilities survey
- Transmission medium to be used
- Reliability vs. cost
- Personnel requirements vs. cost
- Growth vs. expansion capability vs. cost
- Obsolescence

D. Preparation of Specifications

A communications specification is a translation of ideas, concepts, facts, and requirements. Properly prepared and executed, a specification answers these questions:

- What is needed?
- Who needs it?
- How much is needed?
- Where is it needed?
- What results are expected?

If any of the five questions are not answered by the specification, an ambiguous procurement could result.

The preparation of the communications systems specification is the culmination of the planning phase. It is undertaken after the requirements have been developed and the basic concept has evolved into a viable communications plan. Only after the execution of these tasks, can a procurement specification be written and released to communications systems vendors. The premature preparation or release of the communications specification will manifest itself at a later date in the form of change orders. These change orders may result in changes in the final contract cost of the procurement, possible alterations to the form, fit, and even the function of the procured system.

A communications specification may be comprised of the following major parts or sections:

- Introduction
- Communications Operations Review
- System Performance and Criteria
- Circuit Transmission Objectives
- Multiplex or Terminal Equipment Requirements

- Radio, Power Line Carrier Requirements (as appropriate)
- Antenna System Requirements (as appropriate)
- Quality Assurance Monitoring
- Support Facilities Design Criteria
- General Considerations
- Installation
- Bidding Instructions
- Supplementary Terms and Conditions

In the case of leased facilities, the following may be omitted from the above listing:

- Multiplex or Terminal Equipment Requirements
- Radio, Power Line Carrier Requirements
- Antenna System Requirements
- Quality Assurance Monitoring
- Support Facilities Design Criteria
- Installation

The balance of this section is devoted to outlining each of the major sections of the specification. The subtopics of each major section are covered more thoroughly in the REA 66 series bulletins for the particular system being procured, i.e., Power Line Carrier, Microwave, Mobile Radio and Plant Communications.

The following outline provides a logical expansion of each of the above sections into subtopics or elements which, when properly addressed, will provide a comprehensive communications specification:

- Communications Operations Review
    - Communications System Overview
    - Existing System
    - System Interfaces
    - Existing and Planned Facilities Data
    - Projected Communications System and Need
- System Performance and Criteria
    - Message Circuit Noise
    - Message Channel Transmission Requirements
    - Allowable Noise Contributions of Equipments

- System Availability Analysis
- Multiplex System Requirements
- Microwave System Requirements
- System Channelization and Routing

- Circuit Transmission Objectives

  - Subscriber Loop and Trunk Design
  - Net Loss
  - Assignment of Losses
  - Network Transmission Considerations
  - Switching and Signaling
  - Network Protection Criteria

- Multiplex System Requirements

  - Transfer Function Parameters
  - Insertion Loss Versus Frequency
  - Envelope Delay Distortion
  - Carrier Leak and Signalling Levels
  - Absolute Delay
  - Harmonic Distortion
  - Longitudinal Balance
  - Noise Loading
  - Level and Frequency Stability
  - Phase Jitter
  - Crosstalk
  - Impulse Noise
  - Modulation Scheme

- Radio System Requirements

  - RF System Performance Analysis
  - Radio Path Profiles
  - Short Term and Long Term Variations in Transmission Loss
  - Service Probability
  - Radio Equipment Intermodulation Distortion
  - Antenna System Feeder Echo Distortion
  - Basic Intrinsic Noise
  - Thermal Noise Allowance
  - Error Rate Performance
  - Radio Equipment Performance Parameters
  - Meteorological Data

- Antenna System Requirements

  - Frequency Range, Gain and Beamwidth
  - Front-to-Back Ratio
  - Voltage Standing Wave Ratio

- Radiation Pattern
- Beam Deflection
- Mountings and Fittings
- Radomes
- Heating Elements
- Pressurization System
- Transmission Line and Connectors

° Quality Assurance Monitoring

- Performance Tests - System
- Performance Tests - Equipment
- Right of Inspection
- Test Data - Factory and Field
- Test Schedule
- Failure Criteria
- Retest/Fail Criteria
- Test Equipment Requirements

° Support Facilities Design Criteria

- Facility Data Sheets
- Site Selection
- Accessibility
- Utilities
- Grounding, Bonding, Shielding Criteria
- Surveying - Control Reference Points
- Site Development
- Site Plan
- Battery Plant

° General Considerations

- Frequency Allocations
- Manpower Requirements
- Spares
- Environment Control
- Lighting
- Documentation
- Training
- Reliability
- Alarm System
- Maintenance and Maintenance Records

° Installation

- Scope
- Facility Planning
- Standard Installation Practices
- Installation Documentation

- Equipment Placement
- Cabling and Wiring
- Coaxial Cables/Waveguides
- Antenna Towers and Obstructions
- Circuit Breaker and Panel Wiring
- General Safety Requirements

° Bid Instructions

- Correspondence
- Pre-Bid Meeting
- Inspection of Job Sites
- Proposals
- Sealed Price Quotations
- Pricing Guarantee
- Price Breakdown

° Supplementary Terms and Conditions (as may be required)

- Exceptions
- Project Delay - Liquidated Damages
- Standards of Design and Workmanship
- Acceptance
- Notice of Shipment
- Termination of Agreement
- Payment Terms
- Title, Taxes, and Exemptions
- Liens
- Risk of Loss
- Indemnity and Insurance
- Subcontracts
- Compliance with Laws, Ordinances, Rules and Regulations
- Patents
- Force Majeure
- Warranty
- Assignments
- Arbitration

IV. MANAGEMENT

A. General

The need for effective management for and during the entire communications project is of critical importance to the development and implementation of any Power Line Carrier, (PLC), Microwave Line-of-Sight, Plant Communication, or Mobile Radio System.

To effectively manage any of the communications project elements, it is necessary to identify the significant management actions required, to establish their sequence and relationships, and then to direct their accomplishment.

The project management process is a management tool, used to define the project management procedures required to integrate all the significant management actions necessary to provide a suitable, effective system at a minimum cost. This identification and ordered sequence provide a management checklist so that the effort may be efficiently planned in advance to preclude schedule slippages and prevent marginal performance of the communication system.

B. Specific Objectives

All project efforts should be conducted to satisfy the following objectives:

- Insure effective management from the conceptual through the acquisition cutover phases of the required communication system
- Balance the factors of performance, time, cost, and other resources to obtain the required system
- Minimize technical, economic, and schedule risks during development and production efforts
- Document decisions concerning the project
- Establish a discipline for the personnel to follow so that a closed-loop effort is maintained between the functional areas of responsibility; i.e., procurement and production, program control-configuration management, system engineering, test and acceptance, system deployment and logistics
- Establish requirements for flow of information between interested activities

Project Management, as discussed herein, then, is a recommended structure to establish and maintain positive management control of a communication system program's progress.

C. Project Phases and Organization

1. General

The typical communication system project consists, in general, of six phases, incorporating the participation of a number of individuals and organizations, the total number of participants being dependent on the size of the system required. For the most part though, a typical communications project would constitute the following phases and organization.

The project phases normally contingent to any project are the:

- Conceptual Phase
- Definition Phase
- Acquisition Phase
- Installation Phase
- Test and Acceptance Phase
- Cutover Phase

The Operational and Maintenance Phases are continual, beginning immediately after "Cutover," and lasting for the duration of the system's life cycle.

The project phases hereinbefore listed, their sequence and purposes are as follows:

a. Conceptual Phase

The conceptual phase in the life cycle of any communication system project is the period extending from the determination of a broad system requirement or objective, until a definition of objectives is reached. This phase is usually conducted by the borrower management, in conjunction with its engineers, operational personnel, and/or consulting engineer. Its fundamental purpose is to develop requirements and concepts for a system which will satisfy communication requirements, the necessary technology associated with system equipment requirements, a level of confidence in the technical and economic feasibility of system

concepts, preliminary technical development plans and other documents, and any necessary construction program incidental to the definition and acquisition of the system. The conceptual phase is basically an overall planning phase, the results of which are translated into a specific system requirement, summarily into a system definition to be used in the definition phase.

b. Definition Phase

The definition phase in the life cycle of a communication system project is the period extending from the receipt of a system definition until issuance of procurement specifications. However, there will still be some definition required during the acquisition phase to assure that the procurement specifications and directives are satisfied, and that equipment and material supplied meets and complies with all governing criteria. During the definition phase, the technological advances resulting from the conceptual phase, and state-of-the-art are translated into detailed system equipment and system element performance criteria and system engineering and design requirements. The fundamental purpose of the definition phase is to sufficiently and accurately define the cost, schedule, and system elements (equipment, hardware, construction, facilities, programs, and materials) plus the operational personnel and procedural data required to satisfy total system requirements. The definition phase will assure that full scale procurement is not begun until all costs schedules and performance objectives have been sufficiently identified, evaluated against one another (with "trade-offs" considered) and that a very high probability of successful completion of the acquisition phase is established or guaranteed. Sufficient detail must be provided to assure that a firm-fixed price, or guaranteed purchase order can be utilized to provide for procurement of the system equipment, facilities and materials during the acquisition phase.

c. Acquisition Phase

The acquisition phase is the period extending from the receipt of procurement specifications, directives, or purchase orders, at times overlapping or extending into the installation phase, until the receipt of the last item of equipment, facility, or materials has been accepted. The fundamental purpose of the acquisition

phase is to acquire all items of equipment and system elements required to satisfy the total system purchase package and system specification. During the acquisition phase, the engineering staff, in association with the procurement representative, will work in concert with the material supplier to assure compliance with procurement specifications, and develop any detail design in the production of hardware, facilities, procedural data, and training requirements for borrower operational personnel. This effort will be supported by procurement and production schedules relating to the follow-on installation phase, to assure uniform and timely receipt of all system items. During the acquisition phase factory testing for all communications and electrical equipment is accomplished at the supplier's plant or facilities, to assure unit and system compliance with specifications, prior to delivery and acceptance of the items.

d. Installation Phase

The installation phase in the life cycle of the communications project is the period commencing with the initial facility installation, and ending after all system equipment and facilities have been physically installed, tested and accepted, in preparation for the cutover phase. The fundamental purpose of the installation phase is to receive all equipment and materials from the procurement source, and install all such items in conformance with the projected floor plans, system configuration plans, and installation specifications.

e. Test and Acceptance Phase

All functional items of equipment should be individually tested for compliance, prior to integration into the total system complex for final station, link, or system test and acceptance. The test and acceptance criteria are predicated upon the system specification, test procedures and plans, and the pass-fail criteria stipulated in the specification.

f. Cutover Phase

The cutover phase in the project life cycle is that period, usually commencing immediately after test and acceptance of the communications system and extending until the total system is completely operational.

Cutover of the communications system can be accomplished on a link by link basis, or on a systems basis if all link communication facilities are available at the time of cutover. The fundamental purpose of the cutover phase is to cutover the new communications system into an operational status.

V. COST ANALYSIS

A. Introduction

In order to justify the system to management, the factors bearing upon the design and implementation must be thoroughly documented so that the costs associated with the system are related to the requirements. The cost analysis document should provide an overview that encompasses the following:

- A clear statement of the problem and the consequences of continuing without a solution
- A clear statement of the proposed solution, described in functional terms
- A cost-benefit analysis of the alternative solutions which supports the selection of the proposed system
- A list of potential problems
- An implementation schedule and costs

Costing analysis consists of the application of scientific methods in the integrating of the definition, design, planning, manufacture, and implementation of the system into an effective cost model.

The objectives usually stressed for an effective cost model are:

- Assure definition and design of system are on a total system basis
- Assure full integration of engineering effort
- Assure integration of design requirements and engineering specialties
- Assure compatibility of all interfaces within the system as well as with other systems and equipment
- Provide means to control the work breakdown structure throughout the life of the system
- Provide means to evaluate impact of changes on overall system performance, cost, and schedule
- Provide framework of coherent system requirements
- Provide visibility to measure technical performance status
- Document major technical decisions made during the course of a program

If costing analysis is viewed as an input-output management

logic analysis, the inputs are mission (requirements), environmental constraints and measures of effectiveness. The requirements of a communications system might be to provide a voice or data service for some percentage of the time, a performance parameter of a certain signal to noise ratio, various constraints due to processing of messages and quality of service as a measure of effectiveness.

The inputs are translated into functional requirements and will yield fundamental cost parameters. Cost estimating relationships are ascertained and an analysis is performed to evaluate the candidate systems and subsystems which will attain the functional requirements with the technical and cost constraints. Tradeoffs are next performed to decide on an optimum solution. At this point, cost and system effectiveness, which will be discussed later, are brought into play. The next step integrates all elements of the selected approach into a workable solution. During this step, the support analysis is defined in order to perform life cycle cost studies. The output of the systems engineering management logic should be data defining the configuration of the communication system, its design, test and use for equipment, personnel, computer programs, etc.

The entire iterative process leading to a revision of estimates and cost assessments is shown in Figure V-1.

B. Planning and Analysis

The costs associated with developing, procuring, and operating a communication system represent an expenditure of resources to achieve a certain level of system effectiveness. Thus, the careful analysis of candidate system life-cycle costs is essential to determining which alternate methods will achieve system effectiveness most efficiently.

Despite the importance of cost analysis, current literature offers no single "best" methodology or approach. This lack of standardized analysis is caused by uniqueness of systems, changing requirements, changing technology and other complicating factors. The focus of this paragraph is on electronic systems, which present additional special problems in cost analysis. Electronic systems serve diverse and special roles as both primary systems and support systems. Because of this diversity of roles, electronic systems are non-homogeneous in design and operation, making cost analysis difficult and somewhat specialized. As a result, the cost analysis presented here is not intended to be a standardized procedure for "cookbook" analysis. It is structured as a guide to analytical tools and a summary of current writings about practical cost analysis. Various tools of cost analysis and their applications are discussed, and several useful

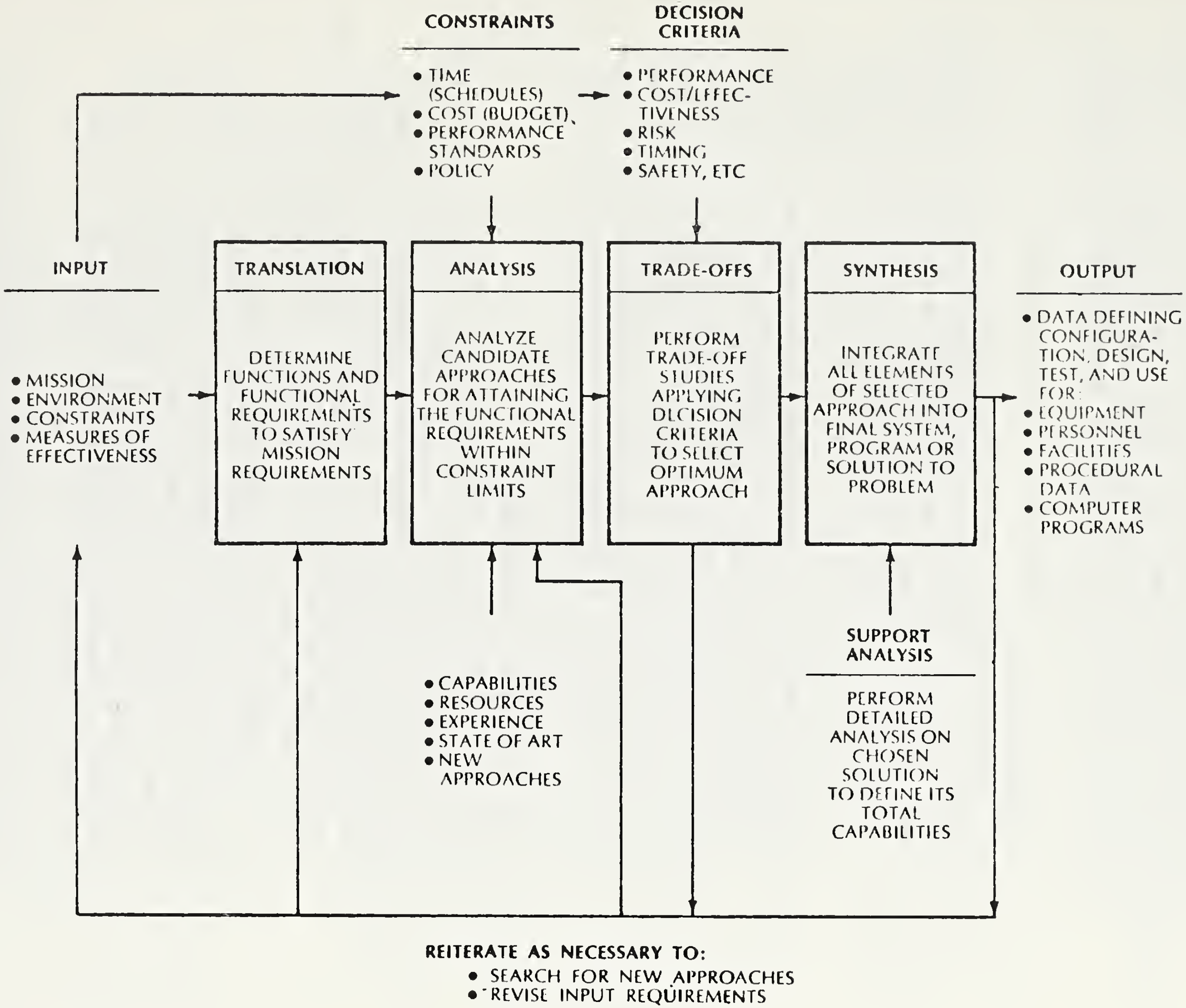

Figure V-1 System Engineering Management Logic

tables and charts are included to aid in individual cost analyses.

Cost and cost-effectiveness analysis are considered by most to be combinations of art and science. The value of an analysis is most often determined by the skill of the analyst, who knows how and when to apply the many tools of cost analysis as they relate to cost-effectiveness decision making. The concepts, tools and methods most useful for cost analysis are summarized in the following paragraphs:

1. <u>Life-Cycle Costs</u>

   The overall, relevant cost implications associated with the decision to develop, procure, deploy, and operate a communications system extend over many years. It is essential, therfore, that all costs relevant to the program decision be carefully considered over the entire system life cycle. The life cycle runs from the date the analysis is made until the system is no longer useful in performing its mission. The latter date can be determined by technological obsolescence, a major change in mission requirements or physical obsolescence. The projected end of the life cycle is difficult to assess, and assumptions must be made about when it is likely to occur. An initial estimate of the time span of the life cycle represents the first bounds to the problem of cost analysis and a point of departure for a continuing analysis.

2. <u>Need for Parametric Analysis</u>

   Cost and cost-effectiveness analyses are dynamic and iterative processes characterized by a continuous effort to improve system effectiveness and efficiency through design improvements and variations of alternatives. To support this extensive analytical process, cost analysis methodology must be both flexible and efficient. The best and most widely used method for achieving this flexibility and efficiency is to use cost as a variable in the analysis. For analysis of subsystems, cost as a function of technological variables is extremely useful. The least cost designs of the communications system are displayed as ranges of total system cost versus system effectiveness (in this case measured in channel capacity) which can be compared to other alternative systems (cable, radio, et cetera) similarly displayed.

   Analyses can be applied to make comparison and choice of systems orderly and efficiently whether the selection process involves fixed effectiveness levels (the least cost

system meeting set requirements) or fixed budget levels (the most effective system meeting a set budget). Also, parametric cost analysis allows variations from these two single point extremes to provide cost and design information associated with relaxing either the budget or the requirements levels. Numerous alternatives can thus be handled efficiently, and extensive data can be reduced to meaningful relationships usable for the complex iterative system design process.

3. Determining Analytical Bounds

All problems must be constrained in scope to allow a point of analytical departure for thorough, efficient study. Since each system under consideration is somewhat unique, the setting of these analytical boundaries is by no means a standardized process. However, criteria for constraining the scope of the problem are available.

The technical and operational parameters most deserving of careful analysis are those of high value and/or with high cost sensitivity to changes in performance. The consequences of error for these parameters could be the invalidation of the analysis by favoring the improper system choice. Other smaller valued parameters, or those with insensitive cost-performance relationships, deserve analysis, but reasonable estimating errors in these cases normally do not alter the ranking of alternatives. The purpose of cost analysis in the system effectiveness context is to support the analysis of system choice rather than to provide highly accurate cost estimates which could be used for purposes such as budget support or contract administration. To achieve this system effectiveness support in an effective and efficient way, careful study to identify these sensitive and important cost elements prior to structuring a cost model will save considerable time and rework during the iterative cost-effectiveness procedure.

4. Alternatives and Comparable Time Frames

System cost and effectiveness analysis is useful only when alternatives are available and valid only when the alternatives are usable during similar time periods. The alternatives must be adequately identified before a useful model and cost analysis can be structured. Similarly, equivalent time frames for system operation must be determined. System alternatives can be obsolete before they are developed, no longer required when developed, leave a requirement unfilled for too long, or have different physical lives. Any of these time factors can confuse the analysis of the system choices;

thus it is essential that alternatives be analyzed and compared only under equivalent time frames. The best systems from each time frame can then be displayed, and a time versus cost-effectiveness tradeoff decision made.

5. Major Cost Variables

Before discussing the specifics of cost analysis, it is important to note the most likely cost variables and how the cost analysis can best be used in refining the decision process. Primarily, cost categories and information should be directly related to the performance criteria as measured by availability, dependability, and capability. Additionally, the cost categories must support both inter- and intra-system tradeoff and optimization analysis. Many of these tradeoff analyses must be made during the iterative cost-effectiveness studies, and readily available parametric cost information greatly facilitates quick analysis of possible improvements to the system under evaluation. The goal of the entire analysis is a presentation of results such as shown in Figure V-2. This final presentation of results facilitates the evaluation of the best choice, displays the sensitivity of system choice to changes in effectiveness level and indicates the cost ramifications of incremental increases. These results are, in turn, presented to the decision maker, who must determine whether a system should be built, and if so, which one. The following sections indicate some of the most useful and widely used methods and tools for achieving the cost portion of cost-effectiveness analysis.

C. System Cost Factors and Considerations

The objective of this phase is to develop and present the performance parameters and analytical functions that relate component and system performance to costs. These analytic functions and parameters are prerequisites to the subsequent analysis that will develop equations, procedures, and the data base for predicting an optimum set of cost estimating relationships. Analysis is defined to be the procedure for determining the performance characteristics of a system or its component, given values for the necessary physical parameters.

The total, relevant life cycle costs mentioned in an earlier paragraph refers to both the direct and indirect cash flow associated with system implementation decisions. These decisions may refer to choosing the most appropriate system, to determining alternative systems for a procurement, or to selecting the best modifications to an existing system to upgrade performance or extend its life. Whatever the type of decision, the

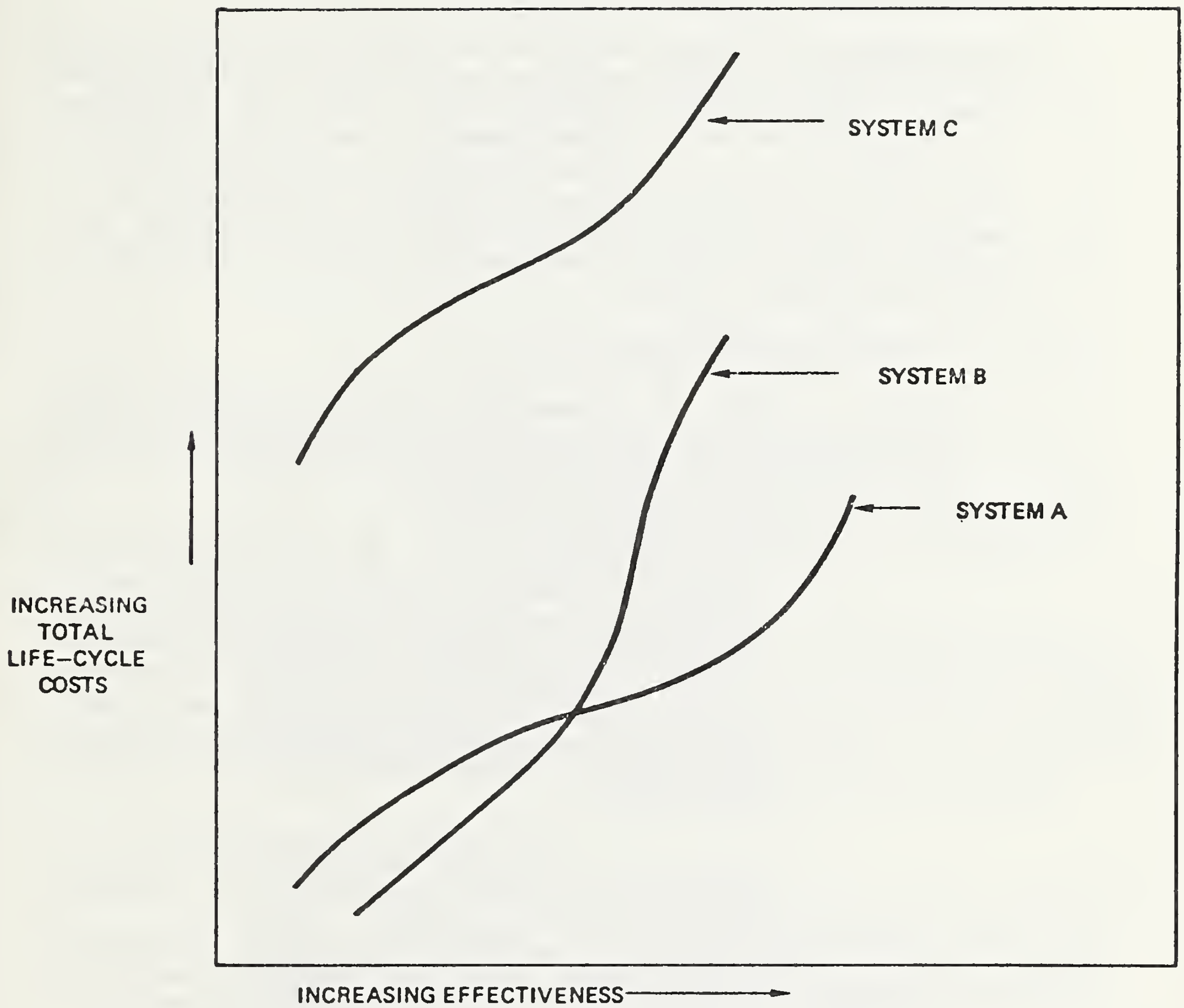

Figure V-2 Typical Cost Effectiveness Curves

general approach to the costing problem is the same. Direct costs can be allocated directly to specific systems while indirect costs are characterized by more uncertainty in allocation. However, some attempt must be made to account for indirect costs, since they could represent a significant portion of the total relevant cost figure for a system.

Cost relevance of cost categories is determined by whether there is significant economic impact of the program decision in these areas. Complete cost analysis of all relevant cost categories is impossible because of time constraints and the environment of uncertainty in cost analysis, but cost categories can be efficiently examined based on the degree of significance in dollar values. Thus the "top down" approach of analyzing the expected highest valued categories first and most carefully is the most prudent approach.

1. Data Base Development

The development of the data base required to support the generation of the cost estimating relationships for each of the systems/equipment categories addressed in this task is based on two major considerations:

- The identification of cost related parameters, which are determined primarily by forecasting methods, rather than through the extrapolation of historical cost data. This is necessary to ensure the usefulness of the cost estimating relationships as a prediction tool and to permit the accommodation of changing technology in the design of systems and production of the equipments.

- The ability to define parameters for which adequate and reliable forecast data are available.

Under these considerations the specific method employed in the data base development utilizes a series of translations and analyses that relate system performance measures to equipment determined technology application parameters. In turn, these parameters are applied to the actual generation of the cost estimating relationships as defined later. One of the principal advantages of this method lies in the ability to determine time dependencies in the relationships. Another feature is that the estimates are essentially free of influence by the current dominant vendors in each of the equipment categories and do not require access to any proprietary data.

The basic method applied in establishing the data base parameters is shown in the prediction loop of Figure V-3. The process applied in this loop is:

a. The basic system parameters (which define the user requirements) are established;

b. The system parameters are translated into equipment requirements; in effect, defining the principal characteristics of the equipment that must be provided to meet the system requirements;

c. The equipment characteristics are then mapped into functional blocks describing the technical functions that constitute the equipment;

d. The functions are then identified in terms of the major technologies that are required to implement the function. This provides the direct access to cost/time performance data;

e. The technology cost/time performance data is then combined with derivative support factor data to establish a parametric data base that can be exercised to develop the appropriate cost estimating relationships.

In particular, the user requirements may include factors relating to operation and maintenance, reliability/maintainability (or, alternatively, life cycle cost factors), initial cost minimization, or other items that directly affect equipment requirements or the functional makeup of the equipment requirements or the functional makeup of the equipment.

2. System Parameter Field

The starting point in the development of the data base lies in the establishment of the system parameter field. The basic breakdown used will quantify or bound the following system application-related parameters for each equipment category:

- System channel characteristics (e.g., channel width, throughput rate, error rate, signal-to-noise ratio (where appropriate for the particular equipment category)
- Multichannel characteristics (where applicable)
  - Capacity
  - Co-channel interference requirements
  - Isolation/idle channel noise

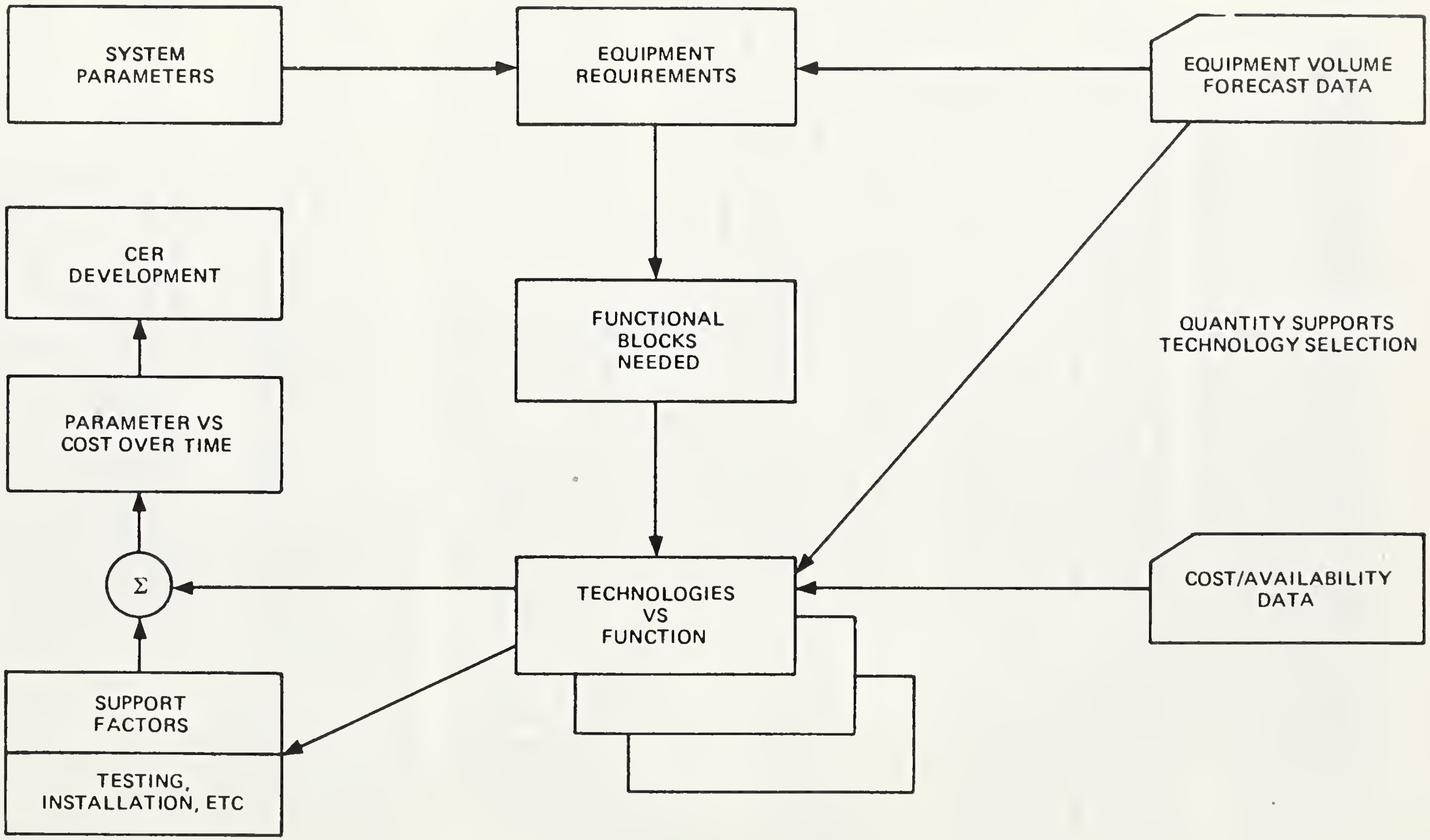

Figure V-3 Prediction Loop

- Interference or security requirements
- Interface characteristics
- Station/Channel Availability and Reliability/ Maintainability Factors
- Equipment Environmental Requirements
- Prime Power Requirements
- Physical Equipment Requirements
- Logistics and Support Requirements for Equipments
- Special Packing/Shipping or Installation Requirements
- System and Equipment Test/Acceptance Criteria

The definition and quantification of these other parameters should be translated into derivative equipment requirements to provide the equipment requirements profile.

3. <u>Collection Task</u>

Because forecasting/projections are used in defining the data base content, no proprietary information is required. From the identification of the desired data, the principal effort is concerned with collection from widely dispersed, but generally accessible, sources. In certain technological areas, proponents of the technology make available the trend curves, cost data and expected performance profiles in order to promote the technology itself.

The sources, although diverse, will include:

- Technical journals and publications applicable to the specific areas of technical interest
- Quasi-technical periodicals
- Manufacturers' data sheets and promotional materials
- Technical forecasts and compilations from public and private sources
- Direct vendor contacts

4. <u>Development of Cost Models</u>

A cost model is a simplification of reality which can be subjected to parametric manipulation for use as an analytical tool. Before such a model can be devised, a certain

amount of information about the systems and their missions must be available. This type of information is summarized as follows:

- Overall System Description
  - Performance requirements for subsystems. These characteristics, or ranges of characteristics, are very important to cost analysis because total cost is particularly sensitive to differences in system characteristics or methods of operation;
  - Primary and support equipment descriptions. Characteristics such as size, weight, environment and numbers of units of both primary and support equipment. This equipment includes facilities support equipment, communications equipment, test equipment and other hardware used as part of the overall system;
  - Installation data -- Information about when and how equipment and facilities are to be merged into an operational system as it affects both costs and timing of the funds flow;
  - Operational and organizational description -- The operational plan and the projected supporting organization as it influences the long-term operating costs of systems;
  - Time frame of interest -- The initial determination of the length of the life cycle for establishing estimates of total operating cost.
- Logistics Concept
  - Maintenance concept -- Repair and general maintenance frequency and methods, and network of facilities required to maintain the equipment in a satisfactory state;
  - In-commission rate data -- Data reflecting the effectiveness goal associated with availability;
  - Supply Network -- Description of the inventory, shipping, warehousing, and ordering procedure to be used to support the system over its operating cycle.

- Personnel Plan

  - Manning policy -- Number and types of personnel required to operate and support the system under various deployment plans;

  - Training system -- Number of schools, capacity, facilities, teaching staff and equipment needed to train personnel on a continuing basis.

With the above general information, the cost model can begin to take shape. A starting point for setting cost breakouts is the system work breakdown structure. The objectives of devising cost categories are ease of data collection and clear presentation of cause-effect relationships. Using these as guidelines, the work breakdown structure categories can be further subdivided, or aggregated, based on selecting categories which relate directly to design and performance variables.

When selecting cost categories, emphasis should be placed on sensitive cost areas. Systems may be preferred only for specific performance goals and constraints, and by varying these goals and constraints, the preferred system can be made to change considerably. Also, the availability of data sources compatible with the selected cost categories is not to be neglected to further facilitate the analytical task. Once suitable cost categories have been determined, it is further beneficial to subdivide each into investment, operation, and maintenance. This step facilitates both estimation and phasing. These subcategories are described as follows:

- Investment costs -- All nonrecurring costs related to procurement, initial deployment of equipment, installations and additional items such as initial training and travel;

- Operating and maintenance costs -- Costs which continue after deployment for equipment and installation equipment, maintenance, pay and allowances, training, power and fuel consumption and support services.

A variety of tools are available to aid in gathering and using cost data. The most widely used and important of these are summarized below.

5. Cost Estimating Relationships (CER)

Cost estimating relationships are statistically derived

relationships using an iterative process of data analysis, formulation and land evaluation which attempt to "explain" the cost of a system or subsystem based on performance or physical characteristics such as weight, radiated power or speed. These relationships generally have the form Cost = $a_1x_1 + a_2x_2 + ,\ldots, a_ix_i + b$ where x is the performance and/or physical characteristic, a is the statistically derived coefficient, and b is a constant derived from the statistical analysis. Uncertainty factors are also available with the cost estimating relationships to indicate probability ranges for the estimates, since no statistical cost relationship is a precise estimator.

Because the available equipment cost data will tend to reflect differing years' costs, it will be necessary to convert the cost data to constant dollars. For this purpose, the various price indices supplied by the Office of Business Economics may be used. These indices consider such items as telephones, speakers, microphones, commercial sound equipment, telephone switching and switchboard equipment, telephone carriers, repeater equipment, telephone instrument sets, other telephone apparatus and components, telegraph apparatus, data sets, radio and television equipment, services on space vehicles, and installation charges on telephone and telegraph equipment. An example of the Communications Equipment Price Index is shown in Table V-1.

The data screening and preliminary evaluation are performed by working with the data, (i.e., tabulating, plotting, and otherwise examining the data both in original form and using transformations). The transformations of interest are those suggested by prior cost analysis experience as well as by the nature of the equipment and the data itself.

As a minimum, logarithmic and semilogarithmic transformations should be considered. It is usually convenient to consider transformations that lead to linear regression problems; however, if suggested by the data, nonlinear transformations can be used.

Figure V-4 illustrates the process of developing the parametric cost estimating relationships.

6. Analogy with Similar Systems

Cost information from systems with similar characteristics is a useful source for preliminary estimates of system costs. This type of estimate is much more uncertain than the type derived from cost estimating relationships, but it is much

Year	Index
1947	95.3
1948	94.4
1949	94.5
1950	96.5
1951	100.5
1952	97.0
1953	93.3
1954	93.8
1955	93.6
1956	95.4
1957	99.0
1958	100.0
1959	100.9
1960	99.4
1961	99.1
1962	100.0
1963	100.7
1964	101.1
1965	100.9
1966	102.6
1967	106.4
1968	112.2
1969	117.8
1970	123.1
1971	131.1
1972	138.1
1973	139.9
1974	149.4
1975 (1st quarter)	167.4
1975 (2nd quarter)	172.9

Table V-1 Communications Equipment Price Index

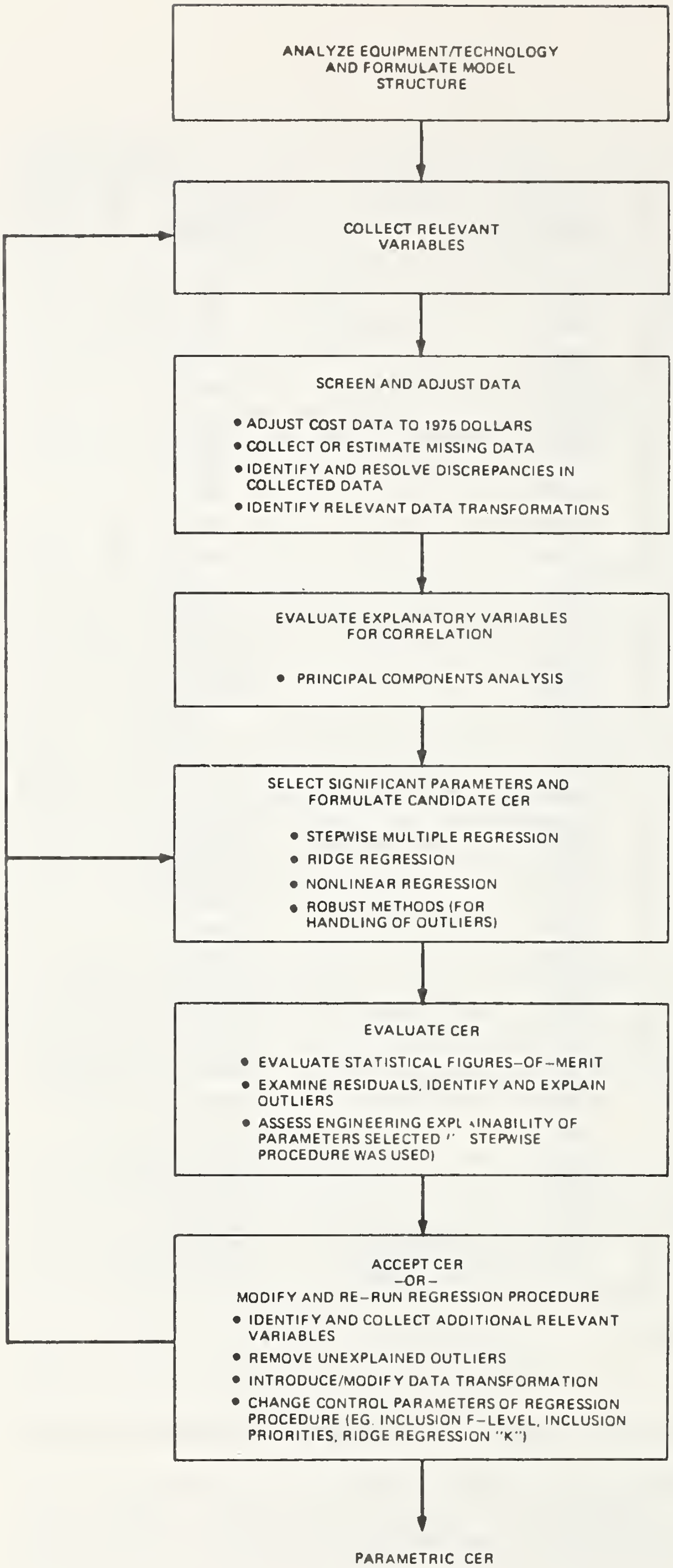

Figure V-4 Project Process, Approaches and Activities Flow Diagram

more applicable because of its flexibility. Sources of such analogous data are other system/project offices throughout the Government and contractors, and central data sources such as the Department of Defense Cost and Economic Information System.

The use of the analogy method leaves considerable uncertainty in the estimate, but gross figures may be acceptable for cutting down the number of alternatives for closer scrutiny. Also, cost sensitivity analyses can be applied to determine the sensitivity of system rankings to cost uncertainties. This type of analysis is discussed in later sections of this chapter.

7. Expert Opinion and Engineering Estimation

Another source of cost estimations is expert opinion. The value and accuracy of these estimates is a direct function of the estimating (not necessarily technical) competence of the expert. In requesting estimates from individuals familiar with the type of equipment to be investigated, it is essential that clear ground rules and boundaries be given for the cost categories. Otherwise, estimates using diverse assumptions would not be consistent. Sources of expert opinion vary considerably, so experts must be sought out individually, based on the characteristics of the cost category to be estimated.

Engineering estimation refers to the extensive "grass roots" form of estimation based on extensive work breakdown structure cost categories. Engineering estimation is an extensive data gathering and data reduction procedure which must be carefully planned and executed to be valid. Instructions, ground rules, and questionnaires must be carefully organized to provide the data required in a single survey because of the time and expense of conducting such an extensive data gathering effort. In addition, the data categories and the questions asked should provide information to support the parametric analyses discussed earlier. Otherwise, a single point cost estimate will result, which is not as useful as parametric estimates for system analysis.

8. Percentage Cost Factors

Many costs can be estimated as percentages of other costs. For example, a rule of thumb for initial spares for electronics equipment is 10 percent of the original investment cost of the equipment. However, this method of estimating is relatively crude and should be used only when more accurate and substantial information is not available.

9. Price Level Adjustments

Price increases over the years in certain sectors of the economy may substantially affect cost estimates for future years. Each industry is different, so a truly accurate projection of prices for future goods and services can be determined only by computing and using inflators for each industry contributing to the system. However, prices in general throughout the communications industry have been increasing at the rate of 4 or 6 percent per year, and a reasonable approximation can be derived using these values.

10. Time Phasing

Two commonly used techniques for establishing the phasing of expenditures are the delay factor method and the percentage time versus percentage cost technique. Delay factor method uses past experience with similar systems and establishes the fair time between application of funds and corresponding milestones or deliveries. These factors are then applied to the system schedule to "back off" the costs to determine the phasing estimate. Percentage time versus percentage cost also uses the system schedule but applies a phasing relationship based on estimates of percent completion at certain milestones. The funds expended are then related directly to the percent completion rates to give an estimate of dollar phasing.

11. Estimating Costs by Specific Categories by Year

There are numerous categories to be considered in establishing a detailed cost model and deriving estimates. The most general of these categories are investment and operations and maintenance cost estimations.

a. Investment Costs

Investment costs include hardware procurement, support facilities, software, initial space and initial personnel relocation and training costs.

One of the largest items in cost analysis is hardware procurement. Most data and estimating techniques are oriented toward providing accurate hardware investment information. Hardware cost categories and subcategories derived from the basic work breakdown structure can be estimated using any or all of these techniques, but accuracy, availability of estimate ranges, and ease of use are the major criteria for selecting the best techniques for accomplishing the task.

The value of support facilities needed for an electronic system is heavily dependent on the type of equipment used in the system. These facilities are buildings, maintenance equipment, roads, and whatever other fixed facilities are required to support the system. Considerable data on these facilities are available for facilities contractors and publications.

The cost of the initial stocking of spare parts is an investment cost because these must be available when the system begins operation. The estimates derived from the hardware procurement analysis are combined with the inventory of spares required by the maintenance plan. If the maintenance plan is not specific, a less accurate estimate may be made by taking initial spares as a percentage of hardware investment cost. This percentage varies according to the system reliability and deployment scheme, so careful analysis is required to get an accurate figure.

The cost of establishing training courses, training the initial personnel, and transporting them to their assigned stations is an additional investment cost. Estimating subcategories with the aid of expert opinion and rule of thumb relationships is the most efficient means of determining these costs.

b. <u>Operation and Maintenance Costs</u>

Operation and maintenance costs include equipment maintenance, facilities maintenance, software updating, leasing of equipment and services, fuel and energy consumption, personnel and contractor technical support services costs.

Direct equipment maintenance costs are the recurring costs which can be clearly associated with specific hardware, such as replacement spares, direct maintenance labor hours, and transportation costs. Indirect costs which are more difficult to assess are overhead allocations for shared facilities and part-time maintenance personnel. It is essential that consistent assumptions about allocation of these indirect costs be made to ensure the validity of the cost analysis.

There may be recurring requirements for revision of computer software. Provisions for such conditions can be entered into the overall cost model.

Lease of equipment and services, such as communications

circuits and transportation service, may be more desirable to the borrower than purchase. An annual provision must be made for these factors.

If the system requires commercial power or consumes fuel on a regular basis, a dollar estimate based on projected consumption is needed. Public utilities and fuel companies can provide accurate rates for their services.

The direct operating personnel required to man the system are determined from the personnel plan. Annual dollar per man rates can then be applied to determine the annual personnel and training costs for the system.

Many systems require contractor technical support services periodically to accomplish recurring changes and upgrading of the system. An estimate should be made of the annual value of these services.

12. Use of Present Value Factors

It should be recognized that the value of money is a function of time; the longer an individual or an institution has the use of money, the more it can earn. Even if the money is not invested, there is the opportunity cost associated with it that represents the amount which could have been earned over a certain time period if the money had been invested. Because of this time value, future expenditures and opportunity costs have different present or current values.

Since money can earn interest, 1,000 dollars is equivalent to 1,100 dollars a year from now, if the present sum can earn interest at 10 percent. Similarly, if it is necessary to wait a year to receive 1,000 dollars due now, 1,100 dollars should be expected rather than 1,000 dollars. As the time span lengthens, the approximate interest is compounded, and the effects on the future dollar value become considerably larger. Thus the timing of payments and receipts can make an important difference in the value of various alternatives.

If a principal sum P is invested at interest rate i, it will yield a future total sum S at a time n years in the future if all of the earnings are retained and compounded. P in the present is entirely equivalent to S in the future because of the compound amount factor. The symbolic expression for this is:

$$S = P(1 + i)^n$$

where $(1 + i)^n$ = the compound amount factor for interest rate i and n years. Similarly, P expressed as a function of S, i, and n is:

$$P = \frac{S}{(1 + i)^n} = S \times PV_{sp}$$

where PV_{sp} = the present value of a single payment S to be made in n years in the future with interest rate i. Therefore, if a payment of 10,000 dollars is to be received in 10 years, a smaller but equivalent sum is acceptable now. If the interest rate is 10 percent, this smaller, equivalent sum is:

$$P = 10{,}000 \times 0.3855 = \$3{,}855$$

Table V-2 lists the present value discount factors for various rates of interest from 1 to 30 years.

A series of different payments or costs for a number of different years can be discounted to present values of these products. To obtain the present value of a stream of like payments for a given number of years, Table V-3 gives a set of cumulative discount factors for various interest rates over 30 years. To find the present value of a stream of annual payments of 1,000 dollars each year for ten years at 10 percent interest, the calculation is:

$$P = 1{,}000 \times 6.145 = \$6{,}145$$

The above illustrates the use and importance of the concept of present value in cost modeling.

An important problem in using present value is the choice of the proper interest or discount rate. There is considerable argument about which rate to use. The assumption about the rate of interest can be subjected to a sensitivity analysis to determine the impact as a result of varying the interest rates.

The length of time to be used for discounting is the same as the system life cycle discussed earlier (this may correspond to the depreciation period). It is most useful when performing the present value calculations to display the cash outflows (procurement, et cetera) and inflows salvage values, savings from early phaseout of systems being replaced, et cetera, on a year-by-year table. The calculations are thus clearly displayed with the cost categories and time phasing to minimize the possibility of errors in the analysis.

Present Value of $1 Expended in Period n

n/1	1 percent	2 percent	3 percent	4 percent	5 percent	6 percent	7 percent	8 percent	9 percent	10 percent
1	.9901	.9804	.9709	.9615	.9524	.9434	.9346	.9259	.9174	.9091
2	.9803	.9612	.9426	.9246	.9070	.8900	.8734	.8573	.8417	.8265
3	.9706	.9423	.9151	.8890	.8638	.8396	.8163	.7938	.7722	.7513
4	.9610	.9239	.8885	.8548	.8227	.7921	.7629	.7350	.7084	.6830
5	.9515	.9057	.8626	.8219	.7835	.7473	.7130	.6806	.6499	.6209
6	.9421	.8880	.8375	.7903	.7462	.7050	.6663	.6302	.5963	.5645
7	.9327	.8706	.8131	.7599	.7107	.6651	.6228	.5835	.5470	.5132
8	.9235	.8535	.7894	.7307	.6768	.6274	.5820	.5403	.5019	.4665
9	.9143	.8368	.7664	.7026	.6446	.5919	.5439	.5003	.4604	.4241
10	.9053	.8204	.7441	.6756	.6139	.5584	.5084	.4632	.4224	.3855
11	.8963	.8043	.7224	.6496	.5847	.5268	.4751	.4289	.3875	.3505
12	.8875	.7885	.7014	.6246	.5568	.4970	.4440	.3971	.3555	.3186
13	.8787	.7730	.6810	.6006	.5303	.4688	.4150	.3677	.3262	.2897
14	.8700	.7579	.6611	.5775	.5051	.4423	.3878	.3405	.2993	.2633
15	.8614	.7430	.6419	.5553	.4810	.4173	.3625	.3152	.2745	.2394
16	.8528	.7285	.6232	.5339	.4581	.3937	.3387	.2919	.2519	.2176
17	.8444	.7142	.6050	.5134	.4363	.3714	.3166	.2703	.2311	.1978
18	.8360	.7002	.5874	.4936	.4155	.3503	.2959	.2503	.2120	.1799
19	.8277	.6864	.5703	.4746	.3957	.3305	.2765	.2317	.1945	.1635
20	.8195	.6730	.5537	.4564	.3769	.3118	.2584	.2146	.1784	.1486
21	.8114	.6598	.5376	.4388	.3589	.2942	.2415	.1987	.1637	.1351
22	.8034	.6468	.5219	.4220	.3419	.2775	.2257	.1839	.1502	.1229
23	.7954	.6342	.5067	.4057	.3256	.2618	.2110	.1703	.1378	.1117
24	.7876	.6217	.4919	.3901	.3101	.2470	.1972	.1577	.1264	.1015
25	.7798	.6095	.4776	.3751	.2953	.2330	.1843	.1460	.1160	.0923
26	.7721	.5976	.4637	3607	.2812	.2198	.1722	.1352	.1064	.0839
27	.7644	.5859	.4502	.3468	.2679	.2074	.1609	.1252	.0976	.0763
28	.7568	.5744	.4371	.3335	.2551	.1956	.1504	.1159	.0895	.0693
29	.7493	.5631	.4244	.3207	.2430	.1846	.1406	.1073	.0822	.0630
30	.7419	.5521	.4120	.3083	.2314	.1741	.1314	.0994	.0754	.0573

Table V-2 Discount Factors for Various Rates of Interest

Present Value of $1 Per Period (Received at End of Each Period)

n/i	1 percent	2 percent	3 percent	4 percent	5 percent	6 percent	7 percent	8 percent	9 percent	10 percent
1	.9901	.9804	.9709	.9615	.9524	.9434	.9346	.9259	.9174	.9091
2	1.9704	1.9416	1.9135	1.8861	1.8594	1.8334	1.8080	1.7833	1.7591	1.7355
3	2.9410	2.8839	2.8286	2.7751	2.7232	2.6730	2.6243	2.5771	2.5313	2.4869
4	3.9020	3.8077	3.7171	3.6299	3.5460	3.4651	3.3872	3.3121	3.2397	3.1699
5	4.8534	4.7135	4.5797	4.4518	4.3295	4.2124	4.1002	3.9927	3.8897	3.7908
6	5.7955	5.6014	5.4172	5.2421	5.0757	4.9173	4.7665	4.6229	4.4859	4.3553
7	6.7282	6.4720	6.2303	6.0021	5.7864	5.5824	5.3893	5.2064	5.0330	4.8684
8	7.6517	7.3255	7.0197	6.7327	6.4632	6.2098	5.9713	5.7466	5.5348	5.3349
9	8.5660	8.1622	7.7861	7.4353	7.1078	6.8017	6.5152	6.2469	5.9952	5.7590
10	9.4713	8.9826	8.5302	8.1109	7.7217	7.3601	7.0236	6.7101	6.4177	6.1446
11	10.3676	9.7868	9.2526	8.7605	8.3064	7.8869	7.4987	7.1390	6.8052	6.4951
12	11.2551	10.5753	9.9540	9.3851	8.8633	8.3838	7.9427	7.5361	7.1607	6.8137
13	12.1337	11.3484	10.6350	9.9856	9.3936	8.8527	8.3577	7.9038	7.4869	7.1034
14	13.0037	12.1062	11.2961	10.5631	9.8986	9.2950	6.7455	8.2442	7.7861	7.3667
15	13.8651	12.8493	11.9379	11.1184	10.3797	9.7122	9.1079	8.5595	8.0607	7.6061
16	14.7179	13.5777	12.5611	11.6523	10.8378	10.1059	9.4466	8.8514	8.3126	7.8237
17	15.5623	14.2919	13.1661	12.1657	11.2741	10.4773	9.7632	9.1216	8.5436	8.0216
18	16.3983	14.9920	13.7535	12.6593	11.6896	10.8276	10.0591	9.3719	8.7556	8.2014
19	17.2260	15.6785	14.3238	13.1339	12.0853	11.1581	10.3356	9.6036	8.9501	8.3649
20	18.0456	16.3514	14.8775	13.5903	12.4622	11.4699	10.5940	9.8181	9.1285	8.5136
21	18.8570	17.0112	15.4150	14.0292	12.8212	11.7641	10.8355	10.0168	9.2922	8.6487
22	19.6604	17.6580	15.9369	14.4511	13.1630	12.0416	11.0612	10.2007	9.4424	8.7715
23	20.4558	18.2922	16.4436	14.8568	13.4886	12.3034	11.2722	10.3711	9.5802	8.8332
24	21.2434	18.9139	16.9355	15.2470	13.7986	12.5504	11.4693	10.5288	9.7066	8.9847
25	22.0232	19.5235	17.4131	15.6221	14.0939	12.7834	11.6536	10.6748	9.8226	9.0770
26	22.7952	20.1210	17.8768	15.9828	14.3752	13.0032	11.8258	10.8100	9.9290	9.1609
27	23.5596	20.7069	18.3270	16.3296	14.6430	13.2105	11.9867	10.9352	10.027	9.2372
28	24.3164	21.2813	18.7641	16.6631	14.8981	13.4062	12.1371	11.0511	10.116	9.3066
29	25.0657	21.8444	17.1885	16.9837	15.1411	13.5907	12.2777	11.1584	10.198	9.3696
30	25.8077	22.3965	19.6004	17.2920	15.3725	13.7648	12.4090	11.2578	10.274	9.4269

Table V-3 Cumulative Discount Factors for Various Interest Rates

13. Risk and Uncertainty

There are numerous sources of uncertainty associated with system cost analysis. Generally, the uncertainties are caused by unpredictable changes in requirements, design and schedule, or by cost estimation errors. A study performed revealed major specific causes of cost estimate revision (and error from the original estimate). These are:

- Quantity changes
- Schedule changes
- Major performance requirements change
- Retrofit
- Engineering change - safety
- Engineering change - performance or design failure
- Engineering change - cost saving
- Cost accomplishment failure

There are various devices for evaluating the effects of the uncertainties on the proper system choice. The major tools for handling risk and uncertainty are summarized as follows:

a. Sensitivity Analysis

Cost sensitivity analysis is a means of determining how variations in assumptions (such as the ones listed above) affect the system choice or cost. This analysis is accomplished by varying the major configuration and operational concepts one at a time over the relevant assumption ranges and then determining the effects of each of these changes on system cost and selection. Figure V-5 is an example of the results of a sensitivity analysis of the required number of satellite ground terminals and the selection of a system configuration. If it is known that more than 10 terminals are needed but the upper limit is questionable, the most economical choice is clearly Type B. Therefore, the assumption about the number of terminals above 10 is not critical to the selection of the proper configuration. Cost sensitivity analysis can point out where costs are sensitive to certain key parameters. This type of analysis can also point out ranges of costs which do not change significantly and can identify critical

assumptions in the analysis. These critical assumptions can then be singled out for additional analysis.

b. Regions of Probable Outcomes

The use of regions of probable outcomes is shown in Figure V-6 using a microwave LOS communications system as an example. Clearly, systems B and D are more desirable than systems A and C since the former provide more channel capacity at less cost than the latter systems. The choice between B and D is less certain, however, and is dependent on the desired channel capacity and the decision maker's attitude about cost uncertainty. This type of analysis can greatly reduce the number of serious alternatives and thus greatly simplify the amount of analysis required.

D. Communications Systems Costs

The cost data presented herein covers microwave LOS, power line carrier, mobile radio, and leased systems. The cost data and associated investment cost tables are relatively complete. Such elements as interface equipment, maintenance costs, and end instruments are not covered for borrower owned facilities. Leased costs do, however, include the cost of the end instrument. Costs shown herein are as of the date of issue of this bulletin.

The cost data is for the purpose of budgeting or estimating the cost of a particular system and not for negotiating. Discount factors are not included in the costs as they vary with vendors, and across the country as a whole.

In using the costs given here, it is not necessary to apply large scale factors for safety in estimating. The costs are reasonably accurate to within plus or minus 10 percent with the single exception of land cost. The values listed for land are nominal and should be adjusted for the area under consideration. The costs are given in 1978 dollars.

1. Microwave Line-of-Sight

Table V-4 lists the costs for a single radio transmitter-receiver pair, order wire channel for maintenance, and the voice channel multiplex equipment. The costs represent equipments capable of meeting CCIR/CCITT recommendations: this should not be construed as a standard, but rather as a basis for comparison. It should also be noted that the radio equipment offerings in the 6 GHz region are limited

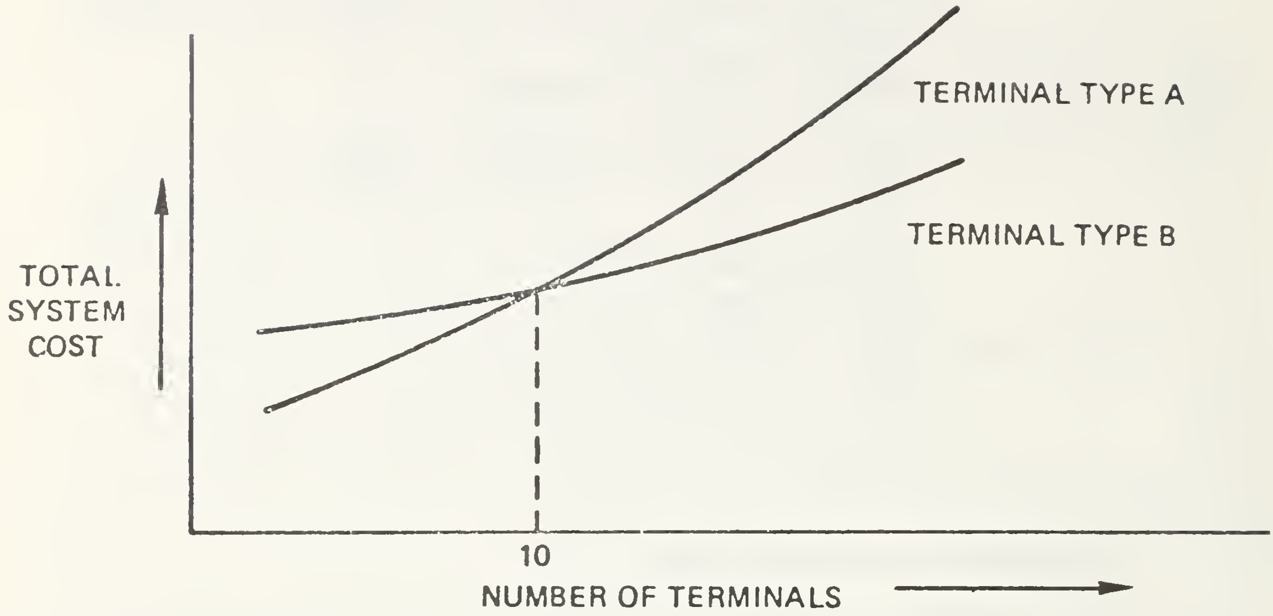

Figure V-5 Sensitivity Analysis of Communications Terminals

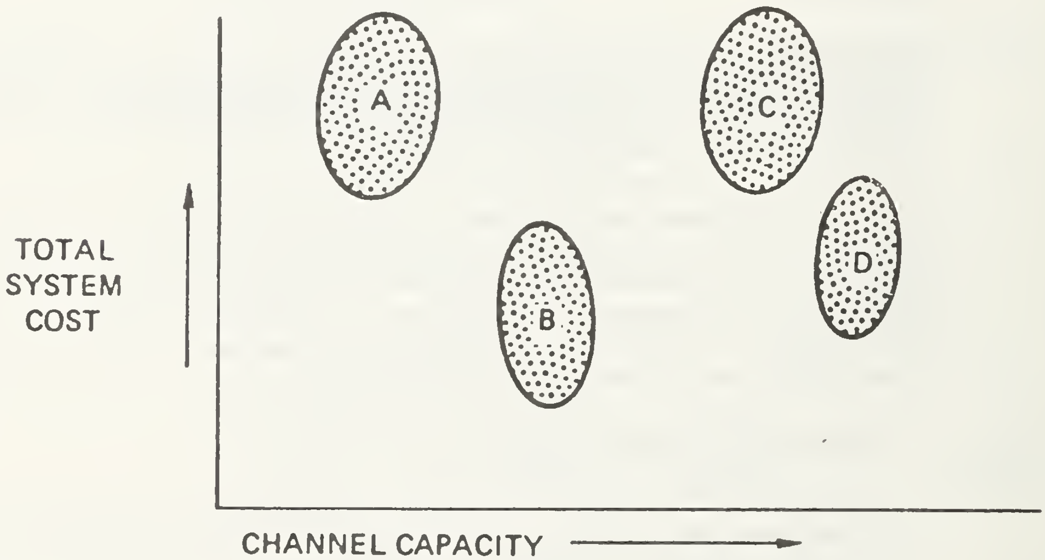

Figure V-6 Regions of Possible Outcomes

Table V-4

Microwave Line-Of-Sight
Radio and Multiplex Equipment

Radio* (Single Radio Transmitter-Receiver Pair)	Cost (Dollars) 2GHz	6GHz
Transmitter-Receiver, 120, 300, or 600 Channels, 1/4 Watt	6000	
Transmitter-Receiver, 120, 300, or 600 Channels, 1 Watt		8300
Transmitter-Receiver, 120, 300, or 600 Channels, 5 Watts	7000	
Transmitter-Receiver, 120, 300, or 600 Channels, 10 Watts	8800	
Transmitter-Receiver, 12-72 Channels, 1 Watt	4000	
Transmitter-Receiver, 12-72 Channels, 5 Watts	5100	
Orderwire Channel	1500	1500

Multiplex	
Direct-to-line voice grade multiplex equipment up to 614 channels	515/Channel

*Hot standby is available in any of the configurations listed at 1.8 times the price shown. Dual space diversity is available at 1.5 times the price shown.

to 120 voice channel bandwidth and above.

Tables V-5 and V-6 list various antennas by size and their accessory equipments respectively. A high performance antenna yields a better overall VSWR and antenna pattern. In some instances it was necessary to list a range of prices due to the offerings by the vendors and frequency range of interest.

Table V-7, tower prices, is for a 40 PSI 13 mm radial ice, 200 km/hour survivable wind. This was selected as an average and is representative of most borrower requirements. The prices shown include fabrication, errection and steel.

Table V-8, Civil Works, is shown here but may also be applied for mobile radio civil works costs.

Table V-9 shows the investment costs for a 120 voice channel non diversity 1 watt radio system.

2. Power Line Carrier

Table V-10 lists the carrier terminal and channelization and signalling equipments. Note that the configurations shown are for single, dual, and four channel systems. When planning it may be well to consider a four channel system initially with modifications to the line equipment where appropriate and as may be possible.

Table V-11 shows the line traps available for various line ratings and inductances.

The line tuning equipment in Table V-12 is given for the several types of coupling that may be used. When applying other than phase-to-ground coupling, additional line equipment and/or carrier terminals may be required. Consult REA Bulletin 66-5 for additional details on equipment configurations.

Audio tone equipment is shown in Table V-13 for either relaying or data requirements.

Table V-14 provides coupling capacitor voltage transformer prices for several different line-to-line voltages.

Table V-15 lists some of the accessories available. Note cabinet and rack prices shown are for additional cabinets since all necessary cabinets have been included within the price data given.

Table V - 5

Microwave Parabolic Antennas

Item	Cost (Dollars) 2 GHz	Cost (Dollars) 6 GHz
Standard (Single Polarized)		
1.8 m	870	700
2.4 m	1320	1150
3.0 m	1920	1750
3.7 m	4070	3900
4.6 m	9770	9500
Standard (Dual Polarized)		
1.8 m	1800	1200
2.4 m	2800	1600
3.0 m	3200	2200
3.7 m	5300	4300
4.6 m	10400	9900
High Performance (Single Polarized)		
1.8 m	3500	3500
2.4 m	4800	4800
3.0 m	5700	5700
3.7 m	8200	8200
4.6 m	12500	12500
High Performance (Dual Polarized)		
2.4 m	5700	5800
3.0 m	6800	7100
3.7 m	9200	9600
4.6 m	12800	13000

Table V - 6

Microwave Antenna Accessories*

Item		Cost (Dollars)
1.	Antenna Mounts	180 - 700
2.	Radomes	
	a. Heated	400 - 1900
	b. Unheated	100 - 1400
3.	Cable Flange Connectors	48 - 220
4.	Hangers	30 per 10
5.	Grounding kit	20
6.	Wall-Roof Feed-through	50
7.	Cable Flange	70 - 250
8.	Dehydrator/Pressurization Assembly	1100 - 2100
9.	Cable	
	a. 7/8" Foam Filled	11.50/m
	b. 1 5/8" Foam Filled	23.00/m
	c. 7/8" Air Dielectric	12.46/m
	d. 1 5/8" Air Dielectric	28.50/m
10.	Waveguide Connectors	70 - 430
11.	Waveguide Flanges	55 - 300
12.	Waveguide	
	a. Elliptical (2 GHz)	43.30/m
	b. Elliptical ([illegible] GHz)	22.63 - 25.50/m

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* Prices are each unless stated otherwise.

Table V - 7

Towers*

Self-Supporting

Height (meters)	Cost (Dollars)
12	11188
18	15752
24	20514
30	25756
37	34487
43	42530
55	53648
61	66165
76	76784
91	88500

Guyed

Height (meters)	Cost (Dollars)
12	3600
18	5520
24	7840
30	10000
37	12600
43	15400
55	20746
61	23200
76	30000
91	37500

Miscellaneous:

Painting	12.25 per meter
Ladders	20.50 per meter
Catwalks	1000.00 each
Tower Lights	325.00
Grounding Kit	725.00

*Price includes steel foundations, and erection.
Designed to 40 PSI and 13 mm of radial ice.

Table V - 8

Civil Works

Item	Cost (Dollars)
1. Access Road Construction (minimal road, 3 meters wide, ditched one side, passable by 2-wheel-drive vehicle 365 days per year):	
a. Relatively level, ordinary terrain	135/lineal meter
b. Steep terrain, blasting required	205/lineal meter
2. Soil-bearing Analysis:	
a. Estimate, as by manual-torque test probe	300/site
b. Formal analysis and report	2900/site
3. Site Plot Plan (one day per site):	
a. Site Plan	400
b. Stake-out	500
4. Azimuthal Determination	
a. Mountain top or inaccessible location, including use of helicopter	600
b. Urban or roadside location	400
5. Concrete in Place (small quantity, as for a small building, footings and slab; tower foundations and anchors, totaling 4 - 10 cubic meters per site):	
a. Low estimate	150/cubic meter
b. High estimate	1100/cubic meter
6. Facility Construction Costs	
a. Low estimate	390/sq. meter
b. High estimate	455/sq. meter

Table V - 9

Investment Cost for Microwave LOS Terminal
(120 Voice Channel, 1 watt Non Diversity Radio System)

Item	Cost (Dollars) 2 GHz	Cost (Dollars) 6 GHz
Electronic Equipment	71400	73100
Antenna System	4600	4300
Tower Equipments	32000	32000
Transmission Line and Accessories	7700	11150
Spare Parts	6150	6300
Installation & Engineering	36000	36000
Support Facilities		
Land (1 acre)	4000	4000
Clearing	1600	1600
Fence (250 meters)	2100	2100
Test Equipment (Pro-rata)	7600	6500
Equipment Building	10080	10080
Hardstand	2050	2050
Total Cost Per Link	185280	189180

Table V - 10

Power Line Carrier Equipment

Carrier Terminals and Channel Equipment

Item	Cost (Dollars)
1. 5 watts, single channel terminal with frequency lock, AGC, & output alarm	5300
a. For 20 watts to above add	900
b. For 100 watts to above add	2600
2. 5 watts, two channel terminal with frequency lock, AGC, & output alarm	5500
a. For 20 watts to above add	900
b. For 100 watts to above add	2600
3. 5 watts, four channel terminal with frequency lock, AGC, & output alarm	5800
a. For 20 watts to above add	900
b. For 100 watts to above add	2600
4. Repeater, 2-way, single or two channel	5600
5. Repeater, 2-way, four channel	5900
6. Repeater, 3-way, single or two channel	5600
7. Repeater, 3-way, four channel	5900
8. Basic channel equipment	1100
a. For voice only to above add	- 0 -
b. For speech plus data to above add	500
c. For compandor to above add	400
d. E & M termination & signalling to above add	600
e. Subscriber dial termination & signalling to above add	700

Table V-11

Power Line Carrier Equipment
Line Traps

(Cost shown in dollars)

Inductance mH	Tuning	400 Ampere	800 Ampere	1200 Ampere	1600 Ampere	2000 Ampere	3000 Ampere	4000 Ampere
0.265	Single	1450	2150	3625	4925	6350	10,150	11,600
0.265	Double	2110	2800	4500	5825	7310	10,950	12,550
0.265	Fixed-Wideband	1950	2680	4350	5100	6600	10,400	11,900
0.265	Adj.-Wideband	2100	2750	4410	5650	7150	10,950	12,450
0.530	Adj.-Wideband	2950	4550	6350	8100	9750	14,050	21,110
1.06	Adj.-Wideband	4150	8050	10,300	12,500	14,800	21,150	
1.06	Untuned	3350	5600	8700	10,350	12,100	17,500	
1.59	Untuned	3785	6275	9825	11,850			

Table V-12

Power Line Carrier*

Line Tuning Equipment

	Item	Cost (dollars)
1.	Single frequency, phase-to-ground coupling	1700
2.	Single frequency, phase-to-phase coupling	2750
3.	Two frequency, phase-to-ground coupling	2450
4.	Two frequency, phase-to-phase coupling	4825
5.	Wideband, phase-to-ground coupling	4300
6.	Wideband, phase-to-phase coupling	3900
7.	Wideband, Mode III coupling	5900

* When applying other than phase-to-ground coupling, additional line equipment and/or carrier terminals may be required. See Bulletin 66-5.

Table V-13

Power Line Carrier Equipment

Audio Tone Equipment

Item	Cost (dollars)
1. Tone System for Relaying	
a. Common Equipment	1750
b. Transmitter Module	410
c. Receiver Module	1325
2. Frequency Shift Keying System for Relaying	
a. Transmitter Module	2300
b. Receiver Module	4000
3. Frequency Shift Keying for telemetering, data, and Supervisory Control	
a. Transmitter Module	2400
b. Receiver Module	2900

Table V-14

Power Line Carrier Equipment

Coupling Capacitor Voltage Transformers

Line-to-Line Voltage (kV)	Cost (Dollars)
34.5	2350
46	3600
69	3780
92	4150
115	4375
138	4825
161	5600
230	6250
345	12000

Table V-15

Power Line Carrier Equipment

Accessories

Item	Cost (dollars)
1. Single-Sideband Test Set	900
2. Party-Line Selector	1500
a. Two telephone terminations-to above add	0
b. Four telephone terminations-to above add	400
c. Eight telephone terminations-to above add	1000
d. Ten telephone terminations-to above add	1450
3. Audio Bridges	
a. 2-wire E&M	1800
b. 4-wire E&M	1700
c. 4-wire local battery ringdown	1750
d. 2-wire common battery ringdown	2100
4. Cabinets and Racks	
a. Swing-rack 1.8 m	600
b. Swing-rack 2.3 m	750
c. Fixed-rack 1.75 m	450
d. Fixed-rack 2.3 m	515
e. Open-rack 1.8 m	300

The investment costs shown on Table V-16 are for a fully equiped four-channel, voice and tone, 100 watt carrier terminal.

Table V-16

Investment Cost for Power Line Carrier Terminal

Item	Cost (dollars)
Carrier Terminal	26900
Line Equipment	16000
Transmission Line and Accessories	1200
Spare Parts	4000
Installation and Engineering	12000
Test Equipment	2100
	62200

3. Mobile Radio

The mobile radio equipment prices are shown on tables V-17 and V-18. Table V-19 provides a separate cost table for the mobile unit, base station, remote consoles, antenna and transmission line installation costs.

The investment costs in Table V-20 are for a 100 watt continuous duty base station having a single remote console. The support facility costs are for a new installation and do not take into consideration any existing facilities.

Table V - 17

Mobile Radio Equipment

Item	Cost (Dollars)
1. Base station, 100 Watt, Continuous Duty tone remote control with private line	2800
2. Base station, 110 Watt, Intermittent Duty tone remote control with private line	2500
3. Mobile unit, 100 Watt	1600
4. Remote console, tone control, microphone, and private line receive switch	900
5. Remote desk set, private line monitor switch and intercom switch	500
6. Base station repeater, 100 Watt	2600
7. Base station repeater, 100 Watt, with DC control	2700
8. Base station repeater, 100 Watt, with tone control	3050
9. Duplexer for high band - UHF operation	300
10. Noise blanker	150
11. Lightning protection kit	90
12. Tone encoders:	
Single Tone	70
Five Tone	105
13. Tone decoders:	
Base station	195
Repeater	115
Mobile	180

Table V - 18

Mobile Radio Antennas and Accessories

Item	Cost (Dollars)
1. Base station antennas	
a. Ground plane, unity gain	100
b. Coaxial, unity gain	110
c. Side mount, up to 12dB gain	250 - 700
d. Bi-directional, 3.6dB gain	225
e. Keyhole pattern, 10dB gain	600
f. Broad band, 3dB or 6dB gain	150
g. Semi-circular pattern, 5dB gain	300 - 800
h. Broadband super gain, 9dB or 12dB gain	685
i. Broad directional, 7dB gain	200 - 1000
j. Para-Corner directional reflector, 8dB gain	150 - 700
k. Broad band Elliptical, 4dB gain	100
l. Broad band Elliptical, 8dB gain	210
2. Mobile unit antennas	
a. Standard, 2.5dB gain	30
b. Standard, 5dB gain	30
c. Base loaded	30
3. Bandpass cavities	
a. Single	105
b. Dual	215
4. Wall/roof feed through connector	20
5. Connectors	8 - 25
6. Interference filter	150 - 800
7. Circulator	225 - 700
8. Isolator	250 - 800
9. Tunable transmitter combiner, two frequencies	1200 - 4500
10. Antenna mounting clamps	20/each
11. Cable, 50 ohm	
a. 1/2"	3.28/meter
b. 7/8"	8.20/meter
c. 1 5/8"	18.76/meter
Cable Connector kit	
a. 1/2"	28
b. 7/8"	54
c. 1 5/8"	190

Table V - 19

Mobile Installation Prices

Item	Cost (Dollars)
1. Base station	150
2. Remote consoles	100
3. Remote desk sets	380
4. Mobile units	410
5. Antenna and transmission line	190

Table V - 20

Investment Cost for Mobile Radio System
(100 Watt Base Station with Repeater and 10 Mobile Units)

Item	Cost (Dollars)
Electronic Equipment	4400
Antenna System	1250
Tower Equipments	6000
Transmission Line	2300
Spare Parts	900
Installation	750
Support Facilities	
Land	2000
Clearing	800
Fence	2050
Test Equipment	650
Equipment Building	5000
Hardstand	1500

4. Common Carrier Service

Tables V-21 through V-31 provide a comprehensive listing of common carrier communications service rates for several different types of service and leasing arrangements. Whatever service or combination of services the borrower may select, the cost of service, connection charges, and terminal charges should be validated with the local telephone service organization. There may be instances, because of unique requirements and/or other factors, that the rates shown herein may be at variance with the actual service contract negotiated between the borrower and the telephone company.

The key factors in determining the cost of leased service are:

- Total mileage between locations
- Cost per mile for the type of service required
- Service terminal charge

A voice communications user pays the rate as a data communications user. It is the length of time the line is in use and the distance between the users that determines the cost.

Tables V-21 through V-24 provide the tariffs for:

- Direct distance dialing
- Wide Area Telecommunications Service
- 50 Kilobit
- TELEX
- TWX

These are commonly referred to as "switched services." Switched services provide for connecting two or more users over the network via the ordinary dial telephone.

Direct distance dialing, Table V-21, allows the telephone subscriber to use his dial telephone for either voice or data communications. The charge or cost depends on the length of time the line is being used and the distance between calling parties.

Wide Area Telecommunications Service provides voice grade lines for telephone users on the public dial telephone network. The cost of this service is a special bulk rate

service offered by the American Telephone and Telegraph Company (AT&T) for directly dialed station-to-station telephone calls and may be used for either voice or data traffic. The United States is divided into service areas and the coverage from one area to another is determined by the "band" of service to which the user subscribes. A map showing these band designations may be obtained from the local AT&T representatives. Wide Area Telecommunications Service is offered on either a measured time or full business day rate. The basic charge for the measured time covers 10 hours of use per month. The full business day covers 24 hours of use per month. Time in excess of these figures is billed at an additional charge shown in brackets.

The rates shown do not include calls within a state. These must be leased as either in-bound or out-bound Wide Area Telecommunications Service lines that can be used intrastate. The various states' telephone regulatory agencies have published intrastate tariffs that may be consulted by the borrower for determining both service available and cost thereof.

The 50 Kilobit service rate shown on Table V-23 is a measured use high speed data transmission service. The bandwidth provided for this dial-up service is equivalent to 12 voice grade lines or a bandwidth of 48,000 Hertz. This service is used for high speed data, up to 50,000 bits per second, and facsimile transmission. The 50 Kilobit service is limited to major cities and service between these cities. A telephone service company representative should be contacted for additional information regarding service in a particular area. The cost of service is determined on a mileage basis and the amount of time the line is in use.

Table V-24 provides the basic rates for Teletypewriter Exchange Service; TELEX or TWX service. TELEX is a 66 word-per-minute teletypewriter-to-teletypewriter service that uses USASC II code and is available at two transmission speeds - 60 and 100 words per minute. The common carrier is responsible for supplying the teletypewriter terminal connections to the line, and the line services for TELEX service. With TWX the user may provide the terminal instead of leasing it from the common carrier. Terminal costs are shown at the bottom of Table V-24.

Packet switching service, Table V-25, provides a service whereby the packet switching vendor leases the communications lines from the common carrier and supplements the lines with packet switching capability. The packet switching network offers data communications service for transmission speeds from 50 to 56,000 bits per second. Automatic

error detection and correction are used to provide high grade data communications circuits. In packet switching, the user's data are transmitted in groups or packets. Not all the data is transmitted over the same line; some packets of the same message travel different routes. This means of transmission provides additional message security and is transparent to the user. The total monthly cost for packet switching service is comprised of a monthly usage charge per packet, a network access charge, and the network interface equipment charge. These costs are shown on Table V-25 and do not include the costs of the local loop between the customer's office and the central office used by the packet switching vendor. The standard common carrier rates apply for this portion of the service and should be determined by the user in conjunction with the local telephone company and the packet switching vendor. The netowrk interface equipment charges shown at the bottom of the table indicate that the total cost is sensitive to the composition of the data transmission system implemented by the borrower.

Tables V-26 and V-27 show the costs for low-speed private leased lines. These lines are used for data transmission speeds up to 150 bits per second (bps) as follows:

- Type 1001: Up to 30 bps for remote metering and supervisory control
- Type 1002: Up to 55 bps for teletype, data, or remote supervisory control
- Type 1003: Up to 55 bps for remote signaling
- Type 1005: Up to 75 bps for teletype, data, or remote metering
- Type 1006: Up to 150 bps for teletype data or remote metering

Table V-26 shows the interexchange mileage rate as a function of distance and V-27, the service terminal cost for one way transmission (half-duplex) or two-way (full duplex).

Tables V-28 through V-31 provide the leased line costs for series 2000 and 3000 voice grade lines. These are by far the most popular lines used by REA electric systems. They may be used for voice or data transmission and mobile radio extensions. The rates are based on interexchange mileage and the charges are on a per mile per month basis.

The various schedules I through III shown in Tables V-28 through V-30 are based on city designation by category. The local long-lines representative should be contacted for

specific city-category designations.

In addition to the interexchange mileage charges, there are also station/terminal charges for the 2000 and 3000 series voice grade circuits. These are given in Table V-31. It is necessary to consult the local telephone company to obtain accurate costing as they are required by tariff to ascertain the minimum cost per circuit. These circuits have a nominal bandwidth of up to 4000 cycles per second and can provide for data transmission of up to 9600 bps.

Table V-21

Direct Distance Dialing Rates
(Station to Station)

Mileage * Between Stations	Day: Initial 1 Minute	Day: Additional 1 Minute	Evening: Initial 1 Minute	Evening: Additional 1 Minute	Night & Weekend: Initial 1 Minute	Night & Weekend: Additional 1 Minute
1-10	$ .19	$ .08	$ .1235	$ .052	$ .076	$ .032
11-16	.23	.11	.1495	.0712	.092	.044
17-22	.27	.13	.1755	.0845	.108	.052
23-30	.31	.17	.2015	.1105	.124	.068
31-40	.35	.20	.2275	.13	.14	.08
41-55	.39	.24	.2535	.156	.156	.096
56-70	.41	.26	.2665	.169	.164	.104
71-124	.43	.28	.2795	.182	.172	.112
125-196	.44	.29	.286	.1885	.176	.116
197-292	.46	.31	.299	.2015	.184	.124
293-430	.48	.33	.312	.2145	.192	.132
431-925	.50	.34	.325	.221	.20	.136
926-1910	.52	.36	.338	.234	.208	.144
1911-3000	.54	.38	.351	.247	.216	.152

*1.61 kilometers is equal to 1 statute mile.

Table V-22

Interstate Wide Area Telecommunications Service Tariffs

Band 1	Band 2	Band 3	Band 4	Band 5
$1,570.00 ($4.36)	1,640.00 (4.55)	1,660.00 (4.61)	1,670.00 (4.63)	1,675.00 (4.65)
$ 230.00 ($17.25)	238.00 (17.85)	242.00 (18.15)	244.00 (18.31)	245.00 (18.38)
$1,610.00 ($4.47)	1,645.00 (4.56)	1,660.00 (4.61)	1,670.00 (4.63)	1,675.00 (4.65)
$ 234.00 ($17.55)	239.00 (17.93)	242.00 (18.15)	244.00 (18.31)	245.00 (18.38)

Table V-23

50 Kilobit Service

Mileage **	Per Minute or Fraction Thereof
1-50	$0.50
51-150	0.80
151-300	1.25
301-600	1.75
601-1200	2.25
1201-2000	2.75
2001-over	3.25

Usage	Service Terminal* Installation	Service Terminal* Per Month
Facsimile device	$125.00	$275.00
Synchronous data (50,000 bps)	125.00	275.00

*A service terminal is the plug into which the user plugs a modem.
**1.61 kilometers is equal to 1 statute mile.

Table V-24

Teletypewriter Exchange Service
(TELEX or TWX Service)

Between Points in the United States

Mileage *	Per Minute or Fraction Thereof
0-50	$0.20
51-110	0.25
111-185	0.30
186-280	0.35
281-400	0.40
401-550	0.45
551-750	0.50
751-1030	0.55
1031-1430	0.60
1431-2000	0.65
2001-over	0.70

Usage	Terminal	
	Installation	Per Month
60 wpm (model 28 ASR)	$50.00	$119.00
100 wpm (model 33 ASR)	50.00	79.00
100 wpm (model 35 ASR)	50.00	150.00
Customer interface unit	50.00	34.00

*1.61 kilometers is equal to 1 statute mile.

Table V-25

Packet Switched Service Cost

	Network Access Arrangement (Leased Line Port)*			
Transmission Speed (bps)	Installation	High Density (hourly)	Medium Density (hourly)	Low Density (hourly)
50-300	$250.00	$ 75.00	$110.00	$145.00
600	300.00	125.00	185.00	N/A
1200	350.00	150.00	250.00	300.00
2400-56000	400.00	200.00	N/A	N/A

Network Interface Equipment

Item	Installation	Monthly
Basic equipment cost	$600.00	$400.00
Each access port		
50 bps - 300bps	25.00	25.00
600 bps	40.00	40.00
1200 bps	50.00	50.00

*Standard common carrier rates apply for private leased lines between the end office used by the packet switching firm and the user's premises.

Table V-26

Interexchange Rates Per Mile
Per Month for Low Speed Lines

Interexchange Mileage* Rates (per mile per month)**

	First 100	Next 150	Next 250	Next 500	Each Additional Mile
Type 1001	$1.25	$1.00	$0.60	$0.40	$0.25
Type 1002	1.25	1.00	0.60	0.40	0.25
Type 1003	1.25	1.00	0.60	0.40	0.25
Type 1005	1.25	1.00	0.60	0.40	0.25
Type 1006	1.55	1.25	0.80	0.50	0.30

*1.61 kilometers is equal to 1 statute mile.
**Half/full duplex are the same price.

Table V-27

Service Terminals and Channel Terminals
for Low-Speed Lines

Service Terminals (per service terminal per month)
For the first station in exchange

	Installation	Half Duplex	Full Duplex
Type 1001	$52.55	$40.00	$44.00
Type 1002	52.55	40.00	44.00
Type 1003	52.55	40.00	44.00
Type 1005	52.55	40.00	44.00
Type 1006	52.55	60.00	66.00

Each additional station, same exchange

Type 1001	$52.55	$25.00	$27.50
Type 1002	52.55	25.00	27.50
Type 1003	52.55	25.00	27.50
Type 1005	52.55	25.00	27.50
Type 1006	52.55	40.00	44.00

Channel Terminals: A monthly charge of $30.00 applies for each channel terminal of each two-point section except when the termination takes place at an international boundary point. This applies at each end of each circuit segment.

Table V-28

Interexchange Mileage Charge for
Voice Grade Channels - Schedule I*

Applies between a pair of Category A rate centers

Mileage**	Charge			
1	$ 51.00			
2- 14	$ 51.00	+	$1.80 for each mile over	1 mile
15	$ 76.20			
16- 24	$ 76.20	+	$1.50 for each mile over	15 miles
25	$ 91.20			
26- 39	$ 91.20	+	$1.12 for each mile over	25 miles
40	$108.00			
41- 59	$108.00	+	$1.12 for each mile over	40 miles
60	$130.40			
61- 79	$130.40	+	$1.12 for each mile over	60 miles
80	$152.80			
81- 99	$152.80	+	$1.12 for each mile over	80 miles
100	$175.20			
101-999	$175.20	+	$0.66 for each mile over	100 miles
1000	$769.20			
over 1000	$769.20	+	$0.40 for each mile over	1000 miles

Where one rate center is an international boundary point, charge is as determined above, minus $25.00.

* Series 2000 and 3000 voice grade lines.

**1.61 kilometers is equal to 1 statute mile.

Table V-29

Interexchange Mileage Charge for
Voice Grade Channels - Schedule II*

Applies between a pair of rate centers where one rate center is in Category A and the other rate center of the same pair of rate centers is in Category B

Mileage**	Charge				
1	$ 52.00				
2- 14	$ 52.00	+	$3.30 for each mile over	1	mile
15	$ 98.20				
16- 24	$ 98.20	+	$3.10 for each mile over	15	miles
25	$129.20				
26- 39	$129.20	+	$2.00 for each mile over	25	miles
40	$159.20				
41- 59	$159.20	+	$1.35 for each mile over	40	miles
60	$186.20				
61- 79	$186.20	+	$1.35 for each mile over	60	miles
80	$213.20				
81- 99	$213.20	+	$1.35 for each mile over	80	miles
100	$240.20				
101-999	$240.20	+	$0.66 for each mile over	100	miles
1000	$834.20				
over 1000	$834.20	+	$0.40 for each mile over	1000	miles

Where one rate center is an international boundary point, charge is as determined above, minus $25.00.

* Series 2000 and 3000 voice grade lines
**1.61 kilometers is equal to 1 statute mile.

Table V-30

Interexchange Mileage Charge for
Voice Grade Channels - Schedule III*

Applies between a pair of Category B rate centers

Mileage **	Charge			
1	$ 53.00			
2- 14	$ 53.00	+	$4.40 for each mile over	1 mile
15	$114.60			
16- 24	$114.60	+	$3.80 for each mile over	15 miles
25	$152.60			
26- 39	$152.60	+	$2.80 for each mile over	25 miles
40	$194.60			
41- 59	$194.60	+	$2.10 for each mile over	40 miles
60	$236.60			
61- 79	$236.60	+	$1.60 for each mile over	60 miles
80	$268.60			
81- 99	$268.60	+	$1.35 for each mile over	80 miles
100	$295.60			
101-999	$295.60	+	$0.68 for each mile over	100 miles
1000	$907.60			
over 1000	$907.60	+	$0.40 for each mile over	1000 miles

* Where one rate center is an international boundary point, charge is as determined above, minus $25.00.

**1.61 kilometers is equal to 1 statute mile.

Table V-31

Station Terminal Charges for
Voice Grade Channels*

Station Terminal	Installation	Per Month
First station in exchange	$54.00	$25.00
Each additional station in same exchange		
Same user premises as first station	$54.00	$25.00
Different user premises	$54.00	$25.00

* Series 2000 and 3000 voice grade lines

VI. MAINTENANCE AND TRAINING

A. Maintenance

1. General

The operational phase in the life cycle of the communication system is the period extending after cutover until disposition of the system, either removed from, or replaced within the electric power system complex.

In its operational phase, the communication system or upgrade must be maintained in the state of its original design and intended mode of operation in order for it to continue to provide the necessary services. In this instance, the system is no better than the maintenance and testing performed on it, or the personnel providing the same. In other words, except for authorized periods of "down time" to provide for specific testing and maintenance, the system should provide a maximum in availability and maintainability. To accomplish these ends, an effective and continuing maintenance and test program (as developed under the definition phase) must be followed and applied, by qualified and capable maintenance and test personnel, over the total period of the operational phase. Properly developed and applied, the maintenance and test program should serve to retard degradation of the system, even that which comes about as a result of aging of the system. Properly applied and executed maintenance and testing will not only serve to prolong system life and efficiency, but, should unusual degradation occur, discover the degradation in time to prevent system erosion, and provide for timely application of corrective action. Maintenance of the system generally falls into three categores:

- Preventive Maintenance
- Scheduled or Routine Maintenance
- Remedial Maintenance

2. Preventive Maintenance

Preventive Maintenance is that maintenance applied to the system and the system equipment which is intended to preclude, or prevent deterioration or degradation of the system. Such actions as the following can constitute a preventive maintenance program:

- Proper and timely application of the regular or scheduled maintenance program;

- Maintenance of the specified environmental program under which the system operates;
- Provision of continuous and adequate, regulated power to the system to preclude power anomalies which can cause system damage;
- When called for, and required, proper application of lubricants;
- Prevention of system wear and tear by elimination of unnecessary maintenance or tinkering with system equipment;
- Replacement or changeover of equipment or equipment modules, as called for by manufacturer's schedule, in keeping with the schedule;
- Prevention of the gathering of dust and other non-organic material via electrolytic or other gathering action;
- Use of only qualified maintenance and test personnel on the maintenance and test program.

3. Scheduled Maintenance

Scheduled Mainteance is that maintenance applied on a routine or scheduled basis, to the entire system and system components. It is applied in accordance with the developed maintenance plan and augmented or assisted by the manufacturer's projected maintenance procedures specified in the equipment and systems maintenance manuals provided by the equipment manufacturers.

Scheduled maintenance, as the name implies, is conducted on a regular operational time basis, and is very thorough in nature. It must apply and effect, all testing called for in the maintenance plan, adjustment, where required, of all operational equipment, removal and/or replacement of equipment or equipment modules found to be potentially deficient, or possessing characteristics not in keeping with original design, and correct any deficiencies found at time of the maintenance. The time and frequency of application of the scheduled maintenance is usually determined and applied in accordance with manufacturer's specifications for the same. In any case, it should be effectively, and continually applied, if the system is to benefit from its application.

4. Remedial Maintenance

Remedial Maintenance is that maintenance applied to correct any deficiency/ies which may occur as a result of misuse, improper maintenance, or other uncontrolled or unforeseen mishaps. This maintenance is usually unprogrammed, and is only applied when necessary to correct the resultant fault or deficiency. It is correctional in nature only, but applied when needed can forestall additional system deficiencies or malfunctions.

5. Maintenance and Logistic Support

As with all types of operational systems and equipment, the newly installed operational communications system must have not only continuing and adequate system maintenance, plus adequate, capable, and qualified personnel to effect the maintenance, but also a well formulated and effective ongoing logistic support program. A maintenance logistic support program should be so designed and effected to guarantee the availability, at all times, throughout the total life cycle of the system, of all equipment spares, supplies, and materials necessary to support, to the maximum, the system design objectives, and provide for the maximum in operational longevity. A well founded and effective maintenance logistic support program will serve to establish and maintain:

- Adequate stocking and resupply of all equipment spares and materials identified in the maintenance support parameters and concepts developed in the definition phase;
- Means for refining or updating of the initial support program and its concepts, to provide specific directive action in instances of system equipment modification or replacement;
- Guidance for maintenance personnel in the use of and employment of the system spares and materials;
- Direction and guidance for the use of contractor support (if used) in the establishment of contractor maintenance responsibilities, maintenance, repair, and overhaul of system equipment, plus the acceptance of, and criteria for, repaired or overhauled equipment

- Active participation in validation and verification efforts to assure that the maintenance concepts, procedures and spares levels are continuously valid;
- The continuous review of maintenance concepts, plans, and operations for compatibility of total system maintenance characteristics.

The maintenance logistic support program is a vital aspect in the operation of any communications system, one that, if allowed to deteriorate, will most certainly contribute to system degradation, even to system failure.

B. Personnel Training

1. General

The installation of any type of communications system will always project a requirement for education and training of company personnel, especially those concerned with the operation and maintenance of the system. The type and degree of training required will be dictated by the type, complexity, and size of the system installed. Once a decision on the type of system to be employed has been made, comprehensive and effective training programs must be developed and followed for the edification and training of all company personnel concerned. There are usually two types of training programs involved, Operational and Maintenance (O&M). Dependent on the complexity of the system, training programs could consist of:

- Formal Educational Training
- Company Provided Training
- Contractor Provided Training
- On-the-Job Training (OJT)

2. Formal Training

Formal educational training usually is given only to critical or key company personnel, who have a responsibility for overall operation and maintenance of the system, usually employed in an engineering field discipline. The training can be given on a full time basis, for six months to a year's duration, or on a part time basis, under normal company operational hours. As stated, the education or training is in the engineering discipline (electrical or electronic), and covers, along with other subjects, equipment and system design, radio, telephone, and power system

design, radio, telephone, and power system characteristics and features, transmission engineering, etc., to mention a few. The formal type of education is prolonged and in instances of full time application can be very expensive, and therefore only provided to full time, key personnel, projected for long time employment with the company.

3. Company Provided Training

Company provided training, as its name implies, is accomplished at the borrower's facilities (usually by personnel previously trained by the contractor, or possessing formal education and training) on either a routine or as required basis, and generally is based on data contained in the operations and maintenance manuals furnished by the equipment supplier. This training can be considered as refresher-type training provided to company personnel to maintain their efficiency relative to the operation and maintenance of the system. The training also covers any changes in system equipment or design changes adopted, plus any changes brought about as a result of operational experience. The training is for short periods of duration, occupying only the time necessary to apprise company personnel of the subject data, and assure their understanding of the subject.

4. Contractor Provided Training

Contractor provided training is usually conducted at the manufacturer's plant, and is generally of two types:

- Initial training on all types of contractor provided systems equipment and system maintenance;
- Refresher courses, or courses for new company personnel.

The initial training for company personnel is a thorough program covering all aspects of the manufacturer's equipment pertaining to its operation, employment, and maintenance. In the case of a large complex system, the training period can be extensive and involved, requiring successful completion or graduation as a prerequisite for employment by the borrower in the operation and maintenance of the system. The costs involved with the conduct of manufacturer provided training are usually contained in the overall contract price negotiated with the manufacturer.

5. On-the-Job Training (OJT)

This training, as its name implies, is conducted by the

borrower on-the-job, and usually involves the training, on a full time basis, for personnel who are totally unfamiliar with the system or its components (new employees), or for the upgrading of certain personnel who have been associated with the system on less than a full time basis, and who are projected for full time application to the system operation. In the application of OJT, these personnel are supervised in their actions and training by fully qualified personnel who are totally aware of systems operations or maintenance. Completion of an OJT program may qualify the person for full time employment on the system, and provide for merit increases or promotion, or both. It provides the borrower with another qualified system operator or maintenance person.

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*U.S. GOVERNMENT PRINTING OFFICE : 1978 0-620-036/5054

International System of Units

In December 1975, Congress passed the "Metric Conversion Act of 1975." This Act declares it to be the policy of the United States to plan and coordinate the use of the metric system.

The metric system, designated as the International System of Units (SI), is presently used by most countries of the world. The system is a modern version of the meter, kilogram, second, ampere (MKSA) system which has been in use for years in various parts of the world.

To promote greater familiarization of the metric system in anticipation of the U.S. converting to the system, REA is including metric units in its publications. This bulletin has, therefore, been prepared with the International System of Units (SI) obtained from ANSI Z 210-1976 - Metric Practice. Approximately equivalent Customary Units are also included to permit ease in reading and usage, and to provide a comparison between the two systems.

In certain instances, particularly that associated with the telephone industry, the english system of units is still used especially in the matters of tariffs and rate structures.